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Sampling and Analysis of Wastes Generated by Gray Iron Foundries

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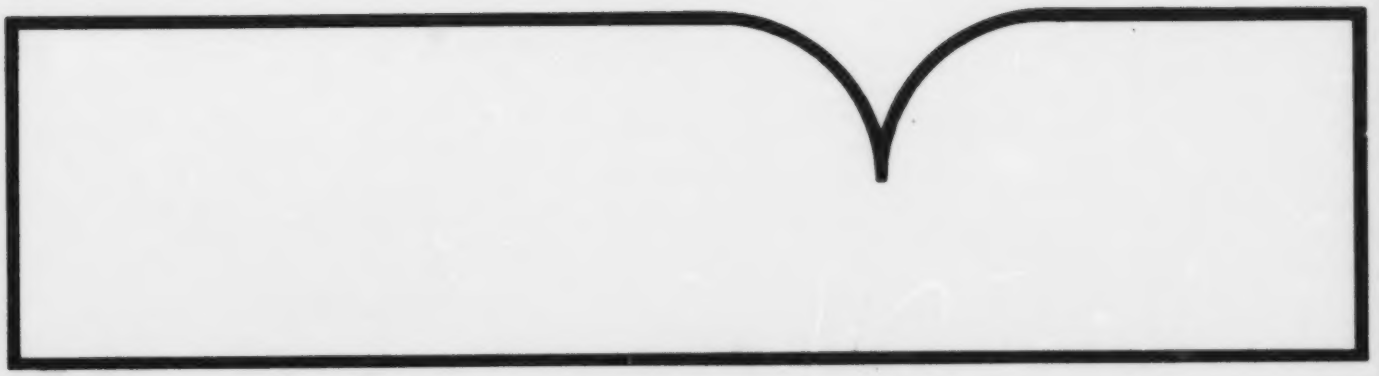

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Office of Solid Waste

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16. ABSTRACT

Thirty (30) wastes generated by 21 gray iron foundries in Pennsylvania and Michigan were sampled and analyzed. The samples were collected by Northrop Services, Inc., in accordance with strict chain-of-custody procedures, and sent to the Environmental Monitoring Systems Laboratory, Las Vegas (EMSL-LV). Three aliquots of each sample were extracted in accordance with the EPA Extraction Procedure (EP) (45CFR261.24). A second set of three aliquots of each sample was digested with nitric acid/hydrogen peroxide. Both the extracts and digests were analyzed for 16 elements by ICP and for cadmium, chromium and lead by atomic absorption spectrophotometry.

At the request of the American Foundrymen Society, aliquots of all raw samples, as well as nine extracts and nine digests, were sent to Dr. W. Boyle, University of Wisconsin, for independent analysis. Twelve aliquots of raw samples, nine extracts and nine digests were analyzed by an analytical laboratory under contract to EMSL-LV. Excellent agreement was obtained between the three laboratories.

Of the 30 samples evaluated for EP toxicity, a total of 9 (30%) exceeded the criteria levels for cadmium and/or lead. None of the extracts exceeded the hazardous waste criterion level for chromium.

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Office of Solid Waste

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The American Foundrymen Society secured the cooperation of the foundries involved. The cooperation of the personnel at each foundry was invaluable in designing the sampling plan and during sample collection.

Dr. William Boyle, University of Wisconsin, under contract to the American Foundrymen Society, and LFE Environmental Analysis Laboratories, under contract to the Environmental Monitoring Systems Laboratory, Las Vegas, conducted analyses of waste samples, split extracts and split digests. We especially thank Dr. Boyle for valuable discussions and for his permission to use his data for this report.

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The commitment of the above and their efforts helped to make the study a success.

INTRODUCTION

Emission control dusts from gray and ductile iron foundry furnaces are generated when the heavy metal contaminants, coke dust, ash, etc., found in the raw material or generated during the manufacturing process, are entrained in the furnace fumes. The particles are entrapped in air pollution control devices and the collected material disposed of. After evaluating the information available, the Agency tentatively determined that the dusts were hazardous wastes within the meaning of the Resource Conservation and Recovery Act (RCRA). The Agency thus proposed, on July 16, 1980 (45 FR 47836), to list such material as a hazardous waste. This conclusion is based on the following considerations:

1. Waste extracts from gray and ductile iron emission control dusts have been shown to contain high concentrations of the heavy metals lead and cadmium. In many cases the concentrations exceeded 100 times the drinking water standards for lead and cadmium, and in some cases exceeded 1,000 times the standard.

2. Large quantities of these wastes are generated annually, increasing the quantity of lead and cadmium available for environmental release.

3. These wastes may be disposed of in wetland or discharge-type areas, increasing the hazardous constituents' migratory potential.

In response to the comments received and in acknowledgement of the economic impact of such a listing, EPA decided to gather further information on gray iron foundry emission control residuals, in order to determine if, in fact, the waste should not be listed. Thus, on January 16, 1981 (46 FR 4616), the Agency deferred final action on listing these wastes pending the outcome of this study.

DESCRIPTION OF THE GRAY IRON AND DUCTILE IRON MANUFACTURING PROCESSES

Close to 1,200 gray iron foundries and 81 ductile iron foundries comprise these industries. Foundries are located throughout the United States, however, a large portion of the plants are found in the Great Lakes area.

In gray iron, most of its carbon content is present as flakes of free graphite. Gray iron is classified into 10 classes based on the minimum tensile strength of a cast bar. The tensile strength is affected by the amount of free graphite present as well as the size, shape and distribution of the graphite flakes. Flake size, shape and distribution are strongly

influenced by metallurgical factors in the melting of the iron and its subsequent treatment while molten, and by solidification rates and cooling in the mold.

Ductile iron (also known as nodular iron, spherulitic iron, etc.) is similar to gray iron with respect to its carbon, silicon and iron content. The important difference between ductile and gray iron is that the graphite in ductile iron separates as spheroids or nodules (instead of flakes as in gray iron) under the influence of a few hundredths of a percent of magnesium in the composition.

Similar types of melting equipment are used to produce both gray and ductile iron, and since the temperature and general metallurgical requirements are also similar for both processes, single foundries can produce both types of iron. Furthermore, since the same types of raw materials are used to produce each type of iron, waste composition also tends to be similar.

Three types of melting furnaces are used for the production of gray iron and ductile iron: cupola, electric arc, and electric induction furnaces. EPA estimates that 95 percent of the furnaces used for producing gray iron and ductile iron are cupola furnaces. The differences among the types of melting furnaces are discussed below.

1. Cupola Furnaces

The cupola furnace is a vertical shaft furnace consisting of a cylindrical steel shell lined with refractories and equipped with a wind box and tuyères for the admission of air. A charging opening is provided at an upper level for the introduction of melting stock and fuel. Near the bottom are holes and spouts for removal of molten metal and slag. Air for combustion is forced into the cupola through tuyères located above the slag well. The products of combustion, i.e., particles of coke, ash, metals, sulfur dioxide, carbon monoxide, carbon dioxide, etc., comprise the cupola emissions. Air pollution emission standards require that these emissions be controlled, and both dry and wet control systems are utilized for this purpose.

2. Electric Arc Furnaces

An electric arc furnace is essentially a refractory hearth in which material can be melted by heat from electric arcs. Arc furnaces are operated in a batch fashion with tap-to-tap times of 1-1/2 to 2 hours. Power, in the range of 500-600 kwh/ton, is introduced through three carbon electrodes. These electrodes are consumed in the process of melting the charge material. They oxidize at a rate of 5 to 8 kg per metric ton of steel (10.5 to 17 lbs/ton). The waste products from the process are smoke, slag, carbon monoxide, carbon dioxide and oxides of metals emitted as submicron fumes. Dry collection air pollution control equipment (usually baghouse) is generally used to control electric arc furnace emissions.

3. Induction Furnaces

Induction melting furnaces have been used for many years to produce nonferrous metals. Innovations in the power application area during the last 20 years made them competitive with cupolas and arc furnaces in gray iron and steel production. This type of furnace has some very desirable features. There is little or no contamination of the metal bath, no electrodes are necessary, the composition can be accurately controlled, good stirring is inherent and, while no combustion occurs, the temperature obtainable is theoretically unlimited. The induction furnace provides good furnace atmosphere control, since no fuel is introduced into the crucible. As long as clean materials such as castings and clean metal scrap are used, no air pollution control equipment is necessary. If contaminated scrap is charged or magnesium is added to manufacture ductile iron, air pollution control devices are required to collect the fumes that are generated.

WASTE GENERATION AND MANAGEMENT

The cupola furnaces in gray and ductile iron foundries require emission control systems. Both wet and dry systems are utilized. Venturi scrubbers are used exclusively for wet scrubbing of cupola furnace fumes and baghouses are used exclusively for dry collection of emissions.

It is estimated that for gray and ductile iron foundries, 10-22 pounds of emission control dust is generated for every ton of metal produced. Approximately 95 percent or 1,185 foundries use cupola melting furnaces. In 1979, 16,741,000 tons of metal were produced by this industry. If 95 percent of this amount is assumed to be produced by the 95 percent of the gray and ductile iron plants, then from 84,000 to 184,000 tons of dust will be generated by the industry per year. This estimate is probably low.

Foundry wastes are land disposed. Wastes from many foundries are monofilled, but others are disposed at municipal or private sanitary landfills which also accept other types of solid waste. Disposal procedures include random dumping and grading, combination with other municipal and industrial wastes, and grading upon deposition followed by application of earth and topsoil cover. The physical settings of the disposal sites vary; locations are generally selected on the basis of availability of land at an appropriate cost within a reasonable haul distance from the foundry. It has been a fairly common practice to dispose of foundry wastes in wetland or discharge-type areas where waste materials can become saturated with surface waters or shallow groundwaters.

The objective of this study was to determine how often the wastes generated by a representative number of gray iron foundries were identified as hazardous by the EPA Extraction Procedure. The parameters of interest were cadmium, chromium and lead with criteria levels of 1, 5 and 5 mg/l, respectively, for identification of a waste as hazardous. A secondary objective was to determine the total concentration of these elements in the wastes studied.

SAMPLING SITES SELECTION

The selection of the foundries to be sampled and the notification of the companies were carried out by the Office of Solid Waste (OSW). The goal of the selection process was to provide a representative cross section of the types of foundries of interest and to minimize the logistical problems and expense associated with sample acquisition.

Factors considered in selecting the sampling sites included the nature of the charge used, furnace type and scrubber type. A telephone survey of all gray iron foundries located in Pennsylvania and Michigan was conducted to obtain data on these factors. A majority of the foundries were reached and provided the requested information. No information was obtained from approximately 15 foundries, either because they would not release the information requested, were closed down during the entire course of the survey, or could not be contacted due to unlisted or constantly busy telephone numbers.

Based on the information obtained through the telephone survey, the furnace charge was divided into five classes:

a) clean
b) contaminated with lubricants only
c) contaminated with paints, coatings
d) combination of b and c
e) other.

Charges classified as (b) or (c) contained 40 percent or more of the respective constituent, while charges classified as (a) were relatively free of (b) or (c). Class (e) represents charges where the composition was unclear or was such that class (b) or (c) scrap constituted less than 30 percent of the total charge.

The information on the individual furnace charge compositions was provided by foundry representatives during a telephone survey, and it was also pointed out by those representatives that the reported charge compositions were characteristic for the individual foundries. Their information was accepted as quoted and formed the basis for the sampling and analytical program. A questionnaire was subsequently distributed to all the foundries that were to be sampled in which a detailed description of the charge was requested. A sample of the questionnaire form is included as Appendix 1.

The scrubbers were of the Venturi and the baghouse type, and the furnaces encountered of the cupola and electric arc or induction type.

The foundries included in this study were selected on the basis of the factors listed above, on the clarity of response to the charge questions and on geographic location. The latter point was important because of the limited resources available for sampling. Therefore, the foundries chosen generally cluster around towns with airports in order to allow the sampling crew to fly in, rent a truck and perform the sampling with a minimum of expense. However, in no case was quality sacrificed for budget.

The selected foundries were notified of the pending sampling and analysis endeavor by OSW. Northrop Services, Inc. (NSI), under contract to EMSL-LV, was to do the actual sampling; their representative established contacts with the selected foundries to discuss sampling details and schedules. Independently, the American Foundrymen Society (AFS) requested the cooperation of the foundries. The AFS also requested from EPA that aliquots of the collected wastes be sent to a laboratory under contract to the AFS, and that samples of mixed wastes be collected, as available, and sent directly to the AFS contract laboratory.

SAMPLING

Two sampling trips were conducted. The sampling trip to Pennsylvania lasted from July 28 to August 2, 1980; the trip to Michigan from August 17 to August 29, 1980. On both trips, scrubber waste samples were collected and sent by Federal Express P-1 mail to the EMSL-LV, and mixed waste samples were sent by Federal Express Standard Air Freight to the AFS contract analytical laboratory at the University of Wisconsin (Dr. W. Boyle). When requested, the foundries received split samples of the wastes collected from their facilities for this program. The sequence of sampling events, a list of essential sampling equipment and a checklist for packing samples for shipment are included as Appendix 2.

It had been hoped that two foundries could be sampled per day; however, in practice this was not always the case. As anticipated, it was possible to sample multiple wastes at some sites. Since the exact nature of the waste storage and disposal facilities at each site were unknown, the sampling team leader used his best judgement to obtain a representative sample (or samples) of each waste of interest. Appendix 3 is a summary of all samples collected. The gray iron foundries that were sampled are identified in Appendix 3 and in the remainder of this report by a two-letter code where the first letter (P or M) identifies the state where the foundry is located (Pennsylvania or Michigan). The foundries are not identified by their address in this report.

One gallon samples were obtained for both solid and liquid wastes. The sample size for baghouse dusts was increased to two gallons during the Michigan trip.

PENNSYLVANIA SAMPLING TRIP

Nine foundries were sampled; 13 scrubber waste samples were collected and sent to EMSL-LV and 10 mixed waste samples were collected and sent to the University of Wisconsin.

All furnaces sampled were cupola furnaces, except at foundry PH, which was an electric arc furnace. The scrubber types were either dry baghouse, wet Venturi, wet or dry quencher (wet from temperature-controlled spray nozzles which come on whenever the incoming furnance air temperature is greater than about 350-400°C), or a combination of a quencher (or Venturi) type and a baghouse.

The EPA questionnaires were left with foundry personnel, with instructions to complete and mail them to Dr. Thomas Gran, NSI, Las Vegas.

Appendix 4 lists the sources and distribution of those samples that were shipped to the EMSL-LV and University of Wisconsin (AFS contractor) for analysis. Almost all of these samples were dry or sludges of relatively low water content. The baghouse dusts were all dry and talc-like in physical appearance. The mixed samples were dry, or, at most, just damp. At most foundries, the mixed waste was primarily composed of casting sand. Smaller proportions of slag were also present, usually as chunks. However, only pieces of slag that were less than about 1/2 inch in diameter were included in the samples of mixed waste sent to the University of Wisconsin. The opening of the cubitainers used for most of the mixed samples is only about 1/2 inch in diameter, and therefore layer pieces could not be shipped.

At some foundries there was no true mixed waste available. In these cases, the sampling team followed a foundry-specific procedure for sampling what was available based on information provided by the plant. In some cases, only casting sand was readily accessible for sampling.

Most wet scrubber equipment had bins for collection of the solids produced. Some of these materials were dry when sampled. Excess water from wet samples was decanted as much as possible before they were deposited into sample containers. The dried samples appeared to be composed primarily of coke particles.

At foundry PB, all wastewater was recycled before it was discarded into a settling lagoon. A sample of this wastewater was collected from a sampling port located just upstream from the point of discharge into the settling pond.

All solid samples were poured or pushed into the cubitainers through a plastic funnel. The funnel was cleaned with paper towels and tap water before each use. Most samples were scooped up with a sampling trowel.

MICHIGAN SAMPLING TRIP

Fourteen furnaces from 12 foundries were sampled; 17 scrubber waste samples were sent to EMSL-LV, and 13 mixed waste samples were sent to the University of Wisconsin.

Two of the furnaces sampled were of the electric arc type (MKK and MR foundries). The sample collected from the MS foundry came from a baghouse scrubber which collected waste from cupola exhaust air. Ten of the furnaces visited had wet scrubbers with some type of Venturi system for collecting waste from cupola exhaust air. Some of these scrubber systems also had wet subsystems (often called quench towers, wet caps, or prequenchers).

Some of the wet scrubber wastes had been treated with base for neutralization, while others were treated with flocculents to aid agglomeration prior to settling. Wet scrubber waste pH was monitored with pH paper during the last half of the Michigan trip.

All plant representatives had completed the EPA questionnaires upon arrival of the sampling team.

Two-gallon samples were taken of all baghouse dusts and one-gallon samples of all the other wastes. Each gallon was composed of many small portions obtained with a trowel or scoop from the most recent (preferably, same day), defined scrubber or mixed waste (preferably, from one "melt"). The trowel samples were taken in a representative pattern throughout the area to be sampled. Guidelines presented in "Samplers and Sampling Procedures for Hazardous Waste Streams" (EPA-600/2-80-018, January 1980) were followed when it was appropriate and practical to do so.

All of the solid waste samples were poured or pushed into cubitainers through a glass or plastic funnel. The funnels were cleaned with paper towels and tap water before each use.

Appendix 5 lists the sources and distribution of those samples that were shipped to the EMSL-LV and University of Wisconsin (AFS contractor) for analysis.

It should be noted that there are two samples numbered 58. An investigation showed that no mix-up between the samples had occurred. The two samples were collected at two different locations, on two different days. Each sample was appropriately packaged and labeled, on the same day it was collected. The first sample was labeled for shipment to the University of Wisconsin, and the second to the EMSL-LV. EMSL-LV personnel who logged in the sample and associated paperwork at Las Vegas confirmed that the correct sample and paperwork had been shipped to Las Vegas.

The baghouse dusts were all dry, gray-white, and talc-like in physical appearance, except for the baghouse scrubbing waste from cupola exhaust air streams. Larger particulates, most probably coke particles, seemed to be mixed in with the fine dust in the latter case.

Many of the Venturi-scrubbed cupolas also had "wet caps" in operation. In almost all cases the larger coke-type particles and fine scrubber waste particles were combined before reaching the point in the waste disposal processes from which samples were collected. The resulting material was usually a wet gray sludge containing coarse to fine particles.

In most cases, wet scrubber waste was sampled from holding tanks or hoppers; therefore, the initial water content was usually high. As much water as possible was decanted or squeezed from the cubitainers.

Unlike any other sample, the scrubber waste sample collected at the MO foundry was noticeably warm for several hours after collection indicating that some kind of reaction was occurring. The unusual behavior of this waste prompted the sampling team to check from this time the scrubber waste pH, since acidity or alkalinity of the scrubber waste at different points in the waste management process could affect the mobility of metals in the waste upon disposal as landfill, etc. It was found that the scrubber waste pH varied from acidic to basic. It was learned that most plants add base to the scrubber waste in the first collection tank to reduce corrosion of pipes, tanks and fittings.

When high lead content was detected in the first Pennsylvania sample analyzed, the sampling team proceeded to look for possible sources of lead among the remaining waste samples. Scrap was therefore carefully examined during the last half of the Michigan trip. Wheel rims were noted at the MO and MS foundries, and at least one lead wheel weight was observed at the MS foundry, contrary to the plant representative's verbal description of his scrap.

In general, scrap used by the foundries appeared to be very clean, and in a number of locations the plant representatives stated that no machine scrap was being used (i.e., only pig iron, casting returns, and/or pieces of structural steel).

PROBLEM SAMPLES

At the ML foundry the wet scrubber waste flows immediately out of the plant via a regulated passage into an open gully, and then into a series of three connected holding ponds. Waste slag is also sluiced into the gully. It was expected that the mixed sample (sample #49), taken from the head of the gully, would be composed almost entirely of the heavier, large slag particles. The physical appearance of the sample confirmed our expectations. The fine scrubber waste particulates probably flow down the gully with the wastewater and settle out in the first or second settling pond. Two liquid samples (sample #50 and #51) were taken to represent the scrubber waste. The first sample was taken from the scrubber sluice water (approximately 1 to 2 grams of settleable solids per gallon sample). The second sample was a composite liquid sample from the first pond. This composite liquid sample was taken from the perimeter of the first pond--at a bend in the flow pattern opposite from the entry point of the sluice water--using the pond sampler and a 1-liter beaker. It was felt that this sample might indicate what metals were leaching from the settled scrubber waste. No solid sample was collected from this foundry since it was not known exactly where the scrubber waste settled out, and it was felt that sampling at an arbitrary location would not produce a representative sample.

The solid wet scrubber waste sample from the MU foundry was taken from a hopper that had been accumulating wet scrubber waste for a month. The most recent waste (about 1/10th of the total) was used in making up the gallon sample. It was felt that this was the best sample that could be taken, since, if it took about 30 days to accumulate 10 gallons, a single day's run would not provide adequate sample size. In addition, the plant representative stated that the composition of the basic furnace charge was almost always the same, and that the location of the hopper provided protection from the elements. There was no way for metals in the scrubber waste to escape from the hopper.

Some recommendations to be considered for future sampling trips are listed in Appendix 6.

SAMPLE SPLITTING AND HANDLING

The foundry waste samples received at EMSL-LV were inspected and immediately assigned to an individual who became responsible for the custody of the samples. All transfers of samples were recorded on the appropriate chain-of-custody forms.

The samples were divided by EMSL-LV personnel into aliquots weighing at least 450 g each. Each aliquot was assigned a number and was randomly either given to the in-house contractor, mailed to LFE or the University of Wisconsin, or added to the secured EMSL-LV sample bank. Appendix 7 lists the aliquots prepared and their disposition.

Solid samples that were dry enough to be dusty were thoroughly shaken in the original sample containers. Aliquots of 450 g or more were then portioned into clean 16-ounce plastic bottles. For some of these samples, two 16-ounce bottles were required per aliquot. Solid samples that were wet but did not contain sufficient liquid to allow a liquid/solid separation by draining were mixed by shaking and squeezing the bottle before removing aliquots.

From solid-liquid samples, the liquid was drained, collected and its volume measured, and the total weight of the residual solids determined. Aliquots (>450 g) of the drained solid were weighed into plastic bottles and a proportional amount of the liquid was returned to restore the original liquid-to-solid ratio.

The liquid sample #8 contained a small amount of filtrable solids. The sample was therefore thoroughly shaken before portioning it into approximately 500-ml aliquots. The samples #50 and #51 contained only a very small amount of filtrable solids. Both samples were filtered and since the weight of the solids were <0.5 percent of the sample weights, the solids were discarded and the filtrates treated as extracts.

On November 21, 1980, aliquots of some of the extracts and digests--prepared at EMSL-LV by NSI--were sent to LFE and the University of Wisconsin for analysis. Appendix 8 identifies the extracts and digests shipped. Extracts #109712 and #109713 were simulated extracts containing 16.0 ppm each of Pb, Cd, and Cr in 0.7 percent nitric acid.

SAMPLE PREPARATION

SAMPLE EXTRACTION

Under strict chain-of-custody procedures, aliquots of the raw foundry waste samples were split into 100-g portions and extracted in triplicate by NSI personnel at the EMSL-LV laboratory facility. The NBS tumbling-type extractor was used throughout the study. The official Extraction Procedure (EP) was followed as specified in the Federal Register (45 FR 33127, May 19, 1980) and explained in detail in Section 7 of "Test Methods for Evaluating Solid Waste," Office of Water and Waste Management, SW-846. A copy of Section 7 of this manual is included as Appendix 9. The extracts were then digested (as outlined in Section 8 of the above manual) for the metals of interest and given to EMSL-LV personnel for analysis.

SAMPLE DIGESTION

Aliquots of the raw foundry waste samples were digested in triplicate by NSI personnel following the procedures detailed in Appendix 10. The digests were given to EMSL-LV personnel for analysis.

SAMPLE ANALYSIS

All extracts and digests were screened for 16 elements using inductively coupled plasma (ICP) emission spectroscopy and then analyzed using atomic absorption spectrophotometry (AAS) for lead, cadmium and chromium. Where indicated by ICP data, additional AAS analyses were performed for metals that exceeded the toxicity characteristic.

SCREENING ANALYSIS USING INDUCTIVELY COUPLED PLASMA (ICP) EMISSION SPECTROSCOPY

All extracts and digests were screened using ICP spectroscopy for the following 16 elements: Al, As, B, Be, Ba, Ca, Cd, Co, Cr, Cu, Fe, Mg, Ni, Pb, V, and Zn. The EMSL-LV instrument used for these screening analyses was an Applied Research Laboratories Inductively Coupled Plasma-Optical Emission Spectrometry instrument with a 27.12 MHz radio frequency generator operated at 1.6 kw. The sample aerosol in this instrument is generated by direct aspiration into a concentric glass nebulizer. The spectrometer used with the plasma excitation source has a 1-meter optical focal length and employs photomultiplier tube detectors for each analytical spectral line. The analyses were conducted in accordance with manufacturer's recommendations for operation of the instrument. For ICP measurements single pass analyses were conducted where one pass consisted of calibration plus measurements on each solution. A Digital Equipment Corporation PDP 11/10 mini-computer was used for data handling and control of the ICP-OES during analysis. The software allows for up to a third order polynomial definition of the calibration curve. This software also permits corrections for interfering element spectral lines (limited to the monitored elements) as well as for stray light created within the spectometer.

ANALYSIS USING ATOMIC ABSORPTION SPECTROPHOTOMETRY (AAS)

All extracts and digests were analyzed for lead, cadmium and chromium (and in some cases other elements) with an automated Perkin-Elmer Model 603 AA spectrophotometer. The procedures used are detailed in Section 8 of "Test Methods for Evaluating Solid Waste", EPA, Office of Water and Waste Management, SW-864. The AAS was equipped with a microprocessor and an automatic sample introduction system. It was interfaced with a PDP-11 computer for conventional flame analysis of fluids suitable for aspiration; it was also equipped with a deuterium background corrector which can compensate for non-analyte absorption. This was a screening-type analysis, and the method of additions was not used.

Whenever the results of the AAS screening analysis of an extract indicated that the amount of cadmium, chromium or lead in the extract exceeded the criteria levels of 1, 5 and 5 mg/l, respectively, another aliquot of the same raw sample was extracted and analyzed for confirmation using the method of additions.

QUALITY ASSURANCE

Each sample location was described and a schematic drawing of the sampling site entered into a hard-bound field log book with tear-out duplicate pages for carbon copies. The sample descriptions included the time and date of collection, exact location, name of sampler and type of sample. The carbon copies were sent with the samples to EMSL-LV. All samples were shipped to EMSL-LV via air carrier (Federal Express). The solid samples were sent in 1-gallon cubitainers with corrugated cardboard packaging; liquid samples were sent in plastic 1-gallon bottles packaged in plastic bags and placed in a wooden box (DOT 19-A-070) cushioned with vermiculite.

All information pertaining to sample splitting, extraction and digestion was recorded in bound laboratory notebooks. All samples, extracts and digests were kept under chain of custody at all times. A copy of the chain-of-custody form is shown as Appendix 11. Aliquots of all raw waste samples shipped to EMSL-LV (except for the liquid samples #50 and #51) were, at the request of the American Foundrymen Society, sent to the University of Wisconsin for independent analysis. Twelve raw waste samples, including three blind splits, were sent to LFE, an independent contractor, for extraction, digestion and analysis. Eight out of the 36 solid waste samples extracted, digested and analyzed at EMSL-LV were blind splits. The analytical results from these blind splits are included in Table 1 and Appendices 12 and 13.

Aliquots of nine extracts and nine digests prepared at EMSL-LV, as well as one simulated extract, were sent to LFE and the University of Wisconsin for independent analysis (see Results and Discussion).

The splitting of samples, extracts and digests was performed by an independent quality assurance team that was in no other way involved in the study. All samples, including all duplicates, were therefore "blind" to the sample preparation team, the analytical team and the contractor.

All extractions and digestions were performed in triplicate. As part of the AAS analytical procedure, a standard was routinely analyzed every ten samples. Filtration blanks were run to determine the effectiveness of filtration equipment cleaning.

Extracts, digests and reagent blanks were analyzed with a single pass procedure for ICP measurements and with a double pass procedure for AA measurements. One analysis pass consisted of calibration plus measurement on each solution.

TABLE 1. SUMMARY OF ATOMIC ABSORPTION SCREENING ANALYSES OF WASTE EP EXTRACTS AND WASTE DIGESTS*

Foundry Code	Field Sample Number	Waste Aliquot Number	EP Extracts (mg/l)			Waste† (mg/kg)		
			Cadmium	Chromium	Lead	Cadmium	Chromium	Lead
PA	1	1085	0.026 ± 0.004	0.06 ± 0.006	3.1 ± 0.7	4.3 ± 0.6	81 ± 3	2140 ± 40
PA	2	1053	0.014 ± 0.003	0.06 ± 0.001	0.6 ± 0.2	1.0 ± 0.0	72 ± 4	180 ± 50
PB	6	1002	1.091 ± 0.003	0.07 ± 0.001	23.8 ± 0.8	79.9 ± 0.9	88 ± 1	20770 ± 370
PB	8	1006	0.010 ± 0.006	BD	BD	BD	BD	BD
PC	12	1035	0.015 ± 0.003	0.06 ± 0.008	0.2 ± 0.04	3.0 ± 0.6	193 ± 40	360 ± 60
PC	12 SP	1042	0.007 ± 0.001	0.07 ± 0.002	0.2 ± 0.03	2.3 ± 0.3	227 ± 9	340 ± 80
PD	16	1068	1.012 ± 0.001	0.07 ± 0.006	109 ± 7	35.0 ± 0.9	43 ± 0.9	18810 ± 2010
PD	16 SP	1075	0.926 ± 0.016	0.06 ± 0.004	120 ± 1	31.3 ± 0.3	43 ± 0.9	17520 ± 100
PE	19	1027	0.013 ± 0.002	0.07 ± 0.001	0.5 ± 0.1	3.3 ± 0.6	33 ± 6	9680 ± 250
PE	19 SP	1033	0.012 ± 0.001	0.07 ± 0.004	0.4 ± 0.04	4.8 ± 2.6	36 ± 7	860 ± 430
PE	20	1064	0.015 ± 0.009	0.07 ± 0.005	0.5 ± 0.3	4.3 ± 0.3	40 ± 1	980 ± 30
PF	22	1045	0.006 ± 0.001	0.07 ± 0.003	0.2 ± 0.2	1.0 ± 0.0	26 ± 2	30 ± 0.7
PF	24	1059	0.027 ± 0.002	0.07 ± 0.002	0.2 ± 0.02	6.8 ± 0.3	75 ± 2	290 ± 4
PG	28	1077	0.081 ± 0.007	0.07 ± 0.003	10.2 ± 2.2	20.0 ± 2.9	78 ± 2	13030 ± 560
PH	34	1022	1.683 ± 0.028	0.07 ± 0.005	10.4 ± 1.5	79.4 ± 0.9	1186 ± 8	10260 ± 20
PI	36	1016	0.021 ± 0.000	0.07 ± 0.003	0.5 ± 0.05	3.2 ± 0.3	133 ± 8	950 ± 50
MJ	40	1101	0.022 ± 0.002	0.10 ± 0.006	0.8 ± 0.1	4.3 ± 0.2	159 ± 13	680 ± 30
MK	42	1211	0.557 ± 0.005	0.05 ± 0.003	0.8 ± 0.04	42.2 ± 0.6	165 ± 4	2650 ± 130
MKK	44	1108	1.319 ± 0.102	0.10 ± 0.006	1.7 ± 0.4	134.1 ± 1.9	1548 ± 24	6210 ± 170
MKK	46	1115	0.023 ± 0.012	0.07 ± 0.002	BD	3.6 ± 0.5	426 ± 57	100 ± 40
MKK	46 SP	1122	0.024 ± 0.002	0.09 ± 0.01	0.2 ± 0.03	3.7 ± 0.1	392 ± 42	110 ± 20
ML	50♦	1123	0.215	0.05	0.2	---‡	---‡	---‡
ML	51♦	1124	0.011	0.07	0.4	---‡	---‡	---‡
MM	52	1125	2.013 ± 0.248	0.11 ± 0.02	25.5 ± 5.7	1063.7 ± 6.4	148 ± 11	29630 ± 1170

(continued)

* Average and standard deviation values are shown for triplicate portions prepared and measured at EPA-Las Vegas.
† Amounts of metals released from the wastes by the digestion procedure employed.
‡ No digestion was performed since waste contained <0.5% filtrable solids.
BD = mg/l values for extracts below 0.004 for Cd, 0.03 for Cr and 0.05 for Pb; 100 x these values for mg/kg in wastes.
SP = Blind splits.

TABLE 1. (Continued)

Foundry Code	Field Sample Number	Waste Aliquot Number	EP Extracts (mg/l)			Waste† (mg/kg)		
			Cadmium	Chromium	Lead	Cadmium	Chromium	Lead
MN	54	1132	0.293 ± 0.053	0.06 ± 0.004	20.4 ± 3.8	17.1 ± 0.6	71 ± 1	2630 ± 20
MN	54 SP	1139	0.243 ± 0.015	0.07 ± 0.02	9.4 ± 0.4	15.5 ± 0.9	74 ± 7	2370 ± 90
MNN	56	1140	0.015 ± 0.006	0.06 ± 0.008	0.6 ± 0.09	2.1 ± 0.0	108 ± 6	370 ± 30
MNN	56 SP	1147	0.015 ± 0.001	0.14 ± 0.13	0.6 ± 0.1	8.5 ± 0.1	322 ± 3	790 ± 30
MO	58	1148	0.019 ± 0.004	0.06 ± 0.002	0.2 ± 0.03	2.3 ± 0.2	76 ± 2	250 ± 30
MP	60	1156	0.062 ± 0.020	0.11 ± 0.009	2.3 ± 0.3	7.5 ± 0.0	301 ± 36	1950 ± 140
MQ	64	1164	0.007 ± 0.001	0.06 ± 0.001	BD	2.9 ± 0.2	105 ± 2	90 ± 4
MR	66	1171	2.279 ± 0.111	0.80 ± 0.06	BD	178.9 ± 8.3	2786 ± 231	390 ± 3
MR	66 SP	1178	2.220 ± 0.085	0.86 ± 0.002	BD	173.7 ± 11.5	2671 ± 72	380 ± 20
MR	68	1179	0.046 ± 0.002	0.29 ± 0.007	BD	8.1 ± 0.2	2210 ± 327	440 ± 20
MR	68 SP	1186	0.062 ± 0.030	0.33 ± 0.005	BD	8.2 ± 0.2	2178 ± 47	450 ± 3
MS	70	1187	0.598 ± 0.057	0.09 ± 0.008	12.6 ± 1.4	116.4 ± 7.1	131 ± 2	3540 ± 330
MT	74	1195	0.010 ± 0.001	0.06 ± 0.004	0.4 ± 0.02	7.5 ± 1.1	148 ± 9	1920 ± 50
MU	78	1203	0.034 ± 0.0006	0.05 ± 0.003	BD	3.0 ± 0.0	122 ± 10	440 ± 50

* Average and standard deviation values are shown for triplicate portions prepared and measured at EPA-Las Vegas.
† Amounts of metals released from the wastes by the digestion procedure employed.
BD = mg/l values for extracts below 0.004 for Cd, 0.03 for Cr and 0.05 for Pb; 100 x these values for mg/kg in wastes.
SP = Blind splits.

Three types of standards were used at EMSL-LV for this project:

1. Spex Industries Mixed Standards for ICP calibration

2. Fisher Atomic Absorption Standard Solutions for AA calibration. These standards were also used to prepare spikes for extracts and digests.

3. NBS Standard Reference Material (SRM 1633) Coal Fly Ash, certified for several elements including Cd, Cr, and Pb, to evaluate the efficiency and precision of the extraction and digestion procedures.

Instruments were calibrated daily when analyses were conducted.

Whenever the AAS screening analysis of an extract produced values for cadmium and/or lead that were above the criteria levels, another aliquot of the same raw waste sample was extracted and analyzed for confirmation by the method of standard additions (see Results and Discussion).

Extract data are reported as mg/l, the units used in the hazardous waste criteria level for toxicity specified in the Federal Register (45 FR 33127, May 19, 1980) for the Extraction Procedure. Digest data are reported as mg/kg of dry sample material to allow convenient estimates for the mass of an element contained in a given load of the solid waste. The concentrations in the extract and digest solutions are not directly comparable because the ratio of final liquid volume to solid weight is 20/1 or more for the extracts and 100/1 for the digests. Furthermore, an EP extract is, according to the definition in the Federal Register quoted above, either the undiluted filtered liquid portion of a waste containing less than 1/2 percent of filtrable solids (examples in this study are samples #50 and #51), or the actual EP extract combined with any liquid that was separated from the sample by filtration before the extraction step. The digestion, however, was always performed on the total solids of the dried samples.

RESULTS AND DISCUSSION

All extracts and digests were screened for 18 elements using ICP spectroscopy. The screening results for the extracts and digests are tabulated in Appendices 12 and 13, respectively. Neither the barium nor the arsenic concentrations in the extracts exceeded 50 percent of the criteria levels (100 and 5 mg/l, respectively), even without background correction, so no attempt was made to analyze for these two elements using AAS.

All extracts and digests were analyzed for cadmium, chromium and lead using AAS without use of the method of additions. The results for the extracts and digests are listed in Table 1. The extracts from the field sample numbers 6, 16, 34, 44, 52 and 66 exceeded the critical concentrations for cadmium of 1 mg/l, and the extracts from the field samples numbers 6, 16, 28, 34, 52, 54 and 70 exceeded the limit for lead (5 mg/l). None of the extracts exceeded the limit for chromium. The analytical results from the aliquots of the raw waste samples sent to the University of Wisconsin (36) and to LFE (12) are tabulated in Appendix 14. The same wastes identified as hazardous by the University of Wisconsin and LFE had also been identified as hazardous at the EMSL-LV. Differences between the values in Table 1 and Appendix 14 are at least in part the result of sample inhomogeneity.

The concentrations of cadmium, chromium and lead in the digests are often three orders of magnitude higher than those in corresponding EP extracts. However, these numbers cannot be directly compared as was explained earlier. To allow for an easier comparison, the amounts of cadmium, chromium and lead extracted from the samples using the EP are listed in Table 2 as percentages of the amounts found in the digests.

In order to confirm these results, fresh aliquots of the wastes with the above field sample numbers were extracted using the EPA Extraction Procedure, the extracts were digested and the digests analyzed for cadmium, chromium and lead. The results are listed in Table 3. The 95 percent confidence intervals for the unspiked extract values in Table 3 can be obtained by multiplying the standard deviation values by 4.30 according to the method of additions procedure in Statistical Theory and Methodology of Trace Analysis, Liteanu, C. and Rica, I., John Wiley and Sons, 1980, pp. 162-166. All lead and cadmium values except one (cadmium in sample #16) were confirmed to exceed the criteria levels.

The occasional large difference between the screening and the confirmatory AAS values is due to the variation between aliquots of the same field sample. This variation is not surprising since many of these wastes were heterogeneous and difficult to mix, as had been explained earlier. Mixing techniques that change the particle sizes (e.g., grinding and milling)

TABLE 2. PERCENTAGE OF CADMIUM, CHROMIUM AND LEAD EXTRACTED FROM THE RAW WASTES BY THE EP*

Foundry Code	Field Sample Number	Waste Aliquot Number	Percentage Extracted		
			Cadmium	Chromium	Lead
PA	1	1085	12 ± 2	2 ± 0.2	2.9 ± 0.6
PA	2	1053	28 ± 6	2 ± 0.03	7 ± 2
PB	6	1002	27.3 ± 0.08	2 ± 0.02	2.3 ± 0.08
PB	8	1006	I	I	I
PC	12	1035	10 ± 2	0.6 ± 0.08	1 ± 0.2
PC	12	1042	6 ± 1	0.6 ± 0.02	1 ± 0.2
PD	16	1068	57.8 ± 0.06	3 ± 0.3	11.6 ± 0.7
PD	16	1075	59.2 ± 1	3 ± 0.2	13.7 ± 0.1
PE	19	1027	7.9 ± 1.2	4 ± 0.06	0.1 ± 0.02
PE	19	1033	5.0 ± 0.4	4 ± 0.2	0.9 ± 0.09
PE	20	1064	7.0 ± 4.2	4 ± 0.2	1 ± 0.6
PF	22	1045	10 ± 2	5 ± 0.2	10 ± 10
PF	24	1059	7.9 ± 0.6	2 ± 0.05	1 ± 0.1
PG	28	1077	8.1 ± 0.7	2 ± 0.08	1.56 ± 0.34
PH	34	1022	42.4 ± 0.7	0.1 ± 0.008	2.03 ± 0.29
PI	36	1016	13 ± 0	1 ± 0.04	1 ± 0.1
MJ	40	1101	10 ± 0.9	1.2 ± 0.08	2 ± 0.3
MK	42	1211	26.4 ± 0.2	0.6 ± 0.04	0.6 ± 0.03
MKK	44	1108	19.67 ± 1.52	0.13 ± 0.008	0.55 ± 0.13
MKK	46	1115	13 ± 7	0.3 ± 0.009	I
MKK	46	1122	13 ± 1	0.4 ± 0.05	4 ± 0.5
ML	50	1123	I	I	I
ML	51	1124	I	I	I
MM	52	1125	3.78 ± 0.47	1.5 ± 0.3	1.72 ± 0.38
MN	54	1132	34.3 ± 6.2	2 ± 0.1	15.5 ± 2.9
MN	54	1139	31.4 ± 1.9	2 ± 0.5	7.9 ± 0.3

(continued)

* Based on AA Data from Table 1 after conversion of the EP values to mg/kg basis.
I indicates Insufficient data (concentrations below detection limits).

TABLE 2. (Continued)*

Foundry Code	Field Sample Number	Waste Aliquot Number	Percentage Extracted		
			Cadmium	Chromium	Lead
MNN	56	1140	14 ± 6	1 ± 0.1	3 ± 0.5
MNN	56	1147	3.5 ± 0.2	0.87 ± 0.81	2 ± 0.2
MO	58	1148	16 ± 4	2 ± 0.05	2 ± 0.2
MP	60	1156	16 ± 5	0.73 ± 0.06	2.4 ± 0.3
MQ	64	1164	5 ± 0.7	1 ± 0.02	I
MR	66	1171	25.48 ± 1.24	0.57 ± 0.04	I
MR	66	1178	25.56 ± 0.99	0.64 ± 0.002	I
MR	68	1179	11 ± 0.5	0.26 ± 0.01	I
MR	68	1186	15 ± 7	0.30 ± 0.005	I
MS	70	1187	10.3 ± 1.0	1 ± 0.1	7.12 ± 0.79
MT	74	1195	2.7 ± 0.3	0.8 ± 0.05	0.4 ± 0.02
MU	78	1203	23 ± 0.4	0.8 ± 0.05	I

* Based on AA Data from Table 1 after conversion of the EP values to mg/kg basis.
I indicates Insufficient data (concentrations below detection limits).

could not be used since breaking up the particles would most likely change the leachability characteristics of the material.

To verify our analytical results, aliquots of digested extracts that exceeded the critical concentrations for cadmium, lead or both, were sent to LFE and to the University of Wisconsin for analysis. Three portions of each sample aliquot had been extracted; an aliquot of one of these extracts (per sample) was sent to each laboratory. A list of these extracts is included in Appendix 9. It should be noted that for identification of the waste aliquots only the first five digits should be compared. Tables 4 to 7 list the LFE data, the University of Wisconsin data, and the corresponding EMSL-LV values. Samples #QC-109712 and #QC-109713 were simulated extracts (containing 16 ppm each of cadmium, chromium and lead in 0.7 percent HNO_3) that were transferred to the LFE, University of Wisconsin and EMSL-LV analysts as blind samples. The reason that the EMSL-LV values in Tables 4 to 7 are not identical to those in Table 1 is that Table 1 lists averages of the values from extracts of three different extractions of the same waste, whereas the values reported in Tables 4 to 7 are in each case only one of the values that were used to get the average value.

TABLE 3. CONFIRMATORY ATOMIC ABSORPTION ANALYSES OF EP EXTRACTS[1,2]

Foundry Code	Field Sample Number	Waste Aliquot Number	Element	Unspiked Reading	Spike Level (mg/l)	Spiked Reading	Spike Recovery (%)	Undiluted Extract (mg/l)	Std. Dev.
PB	6	1004	Cadmium	0.220	0.500	0.719	100	1.089	0.015
					0.750	0.970	100		
					1.000	1.225	100		
PB	6	1004	Chromium	0.03	2.50	2.73	108	0.05	0.15
					4.00	4.39	109		
					5.00	5.54	110		
PB	6	1004	Lead	9.7	5.0	15.0	105	47.3	0.9
					7.5	17.5	104		
					10.0	20.0	103		
PD	16	1076	Cadmium	0.178	0.500	0.676	100	0.888	0.017
					0.750	0.921	99		
					1.000	1.177	100		
PD	16	1076	Chromium	BD	2.50	2.66	106	BD	--
					4.00	4.20	105		
					5.00	5.30	106		
PD	16	1076	Lead	17.7	5.0	22.7	101	89.3	0.7
					7.5	25.2	101		
					10.0	27.6	99		
PG	28	1081	Cadmium	0.026	0.500	0.521	99	0.123	0.012
					0.750	0.771	99		
					1.000	1.024	100		
PG	28	1081	Chromium	BD	2.50	2.67	107	BD	--
					4.00	4.25	106		
					5.00	5.37	107		
PG	28	1081	Lead	2.3	5.0	7.5	103	11.0	0.3
					7.5	10.2	104		
					10.0	12.7	103		
PH	34	1023	Cadmium	0.362	0.500	0.861	100	1.802	0.031
					0.750	1.106	99		
					1.000	1.365	100		
PH	34	1023	Chromium	0.04	2.50	2.68	106	0.12	0.13
					4.00	4.28	106		
					5.00	5.40	107		
PH	34	1023	Lead	3.8	5.0	8.9	103	18.1	0.4
					7.5	11.5	103		
					10.0	14.2	104		
MKK	44	1112	Cadmium	0.290	0.500	0.781	98	1.432	0.035
					0.750	1.036	100		
					1.000	1.291	100		
MKK	44	1112	Chromium	0.04	2.50	2.65	104	0.10	0.21
					4.00	4.21	104		
					5.00	5.36	106		
MKK	44	1112	Lead	BD	5.0	5.4	108	BD	--
					7.5	8.1	108		
					10.0	10.6	106		

(continued)

[1]The deuterim background corrector was not used for the chromium analyses because of inherent corrector limitations and because the EP extract chromium concentrations are below the hazardous waste criteria even without background correction. Readings were made on extracts diluted 5-fold per SW-846.

[2]BD indicates values below the detection limits of 0.005 mg/l for Cd, 0.025 mg/l for Cr and 0.47 mg/l for Pb. Lower detection limits for Pb are obtained when background corrector is not used.

TABLE 3. (Continued) [1,2]

Foundry Code	Field Sample Number	Waste Aliquot Number	Element	Unspiked Reading	Spike Level (mg/l)	Spiked Reading	Spike Recovery (%)	Undiluted Extract (mg/l)	Std. Dev.
MM	52	1130	Cadmium	0.848	0.500	1.344	99	4.184	0.051
					0.750	1.601	100		
					1.000	1.858	101		
MM	52	1130	Chromium	BD	2.50	2.64	106	BD	--
					4.00	4.22	106		
					5.00	5.38	108		
MM	52	1130	Lead	7.8	5.0	12.7	100	38.3	0.9
					7.5	15.4	101		
					10.0	17.9	102		
MN	54	1139	Cadmium	0.073	0.500	0.572	100	0.358	0.023
					0.750	0.817	99		
					1.000	1.076	100		
MN	54	1139	Chromium	BD	2.50	2.60	104	BD	--
					4.00	4.20	105		
					5.00	5.26	105		
MN	54	1139	Lead	2.81	5.0	8.2	107	13.8	0.69
					7.5	10.6	103		
					10.0	13.2	103		
MR	66	1171	Cadmium	0.548	0.500	1.045	99	2.709	0.038
					0.750	1.297	100		
					1.000	1.556	101		
MR	66	1171	Chromium	0.22	2.50	2.77	102	0.99	0.13
					4.00	4.32	103		
					5.00	5.40	104		
MR	66	1171	Lead	BD	5.0	5.0	100	BD	--
					7.5	7.7	103		
					10.0	10.4	104		
MS	70	1193	Cadmium	0.079	0.500	0.568	98	0.379	0.029
					0.750	0.820	99		
					1.000	1.076	100		
MS	70	1193	Chromium	BD	2.50	2.69	108	BD	--
					4.00	4.33	108		
					5.00	5.45	109		
MS	70	1193	Lead	1.5	5.0	6.8	106	7.5	0.5
					7.5	9.3	104		
					10.0	11.8	103		

[1]The deuterium background corrector was not used for the chromium analyses because of inherent corrector limitations and because the EP extract chromium concentrations are below the hazardous waste criteria even without background correction. Readings were made on extracts diluted 5-fold per SW-846.

[2]BD indicates values below the detection limits of 0.005 mg/l for Cd, 0.025 mg/l for Cr and 0.47 mg/l for Pb. Lower detection limits for Pb are obtained when background corrector is not used.

TABLE 4. COMPARISON OF LFE EXTRACTS AA DATA WITH EMSL-LV DATA

Foundry + Sample Code	Waste Aliquot Number	LFE Data (mg/l)			EMSL-LV Data (mg/l)		
		Cadmium	Chromium	Lead	Cadmium	Chromium	Lead
PB6	100222	1.00	0.06	24.4	1.088	0.07	24.4
PD16	106822	0.85	0.06	115	1.011	0.07	116
PG28	107732	0.06	0.10	8.0	0.074	0.07	7.7
PH34	102212	1.57	0.12	11.4	1.692	0.08	11.3
MKK44	110831	1.26	0.08	2.2	1.386	0.10	2.0
MM52	112511	1.75	0.11	21.5	1.852	0.10	21.4
MN54	113231	0.30	0.06	22.4	0.327	0.06	22.9
MR66	117111	2.04	0.87	<0.2	2.166	0.86	<0.05
MS70	118711	0.61	0.09	13.6	0.661	0.10	14.1
Linear Regression							
Slope =		0.946 ±0.018	1.007 ±0.029	0.990 ±0.003			
Intercept =		-0.029 ±0.023	0.003 ±0.009	0.109 ±0.134			
Corr. Coeff. =		0.9988	0.9971	0.9999			
QC STD	109711	14.6	16.4	16.0	16.2	16.2	16.6
True Value =		16.0	16.0	16.0	16.0	16.0	16.0
Agreement =		91%	102%	100%	101%	101%	104%

An attempt was made to correlate high extract values for cadmium and/or lead with the type of furnace, scrubber and charge (as reported by the foundries in the questionnaires). Those variables are displayed in Table 8. All extracts from the three wastes produced by the electric arc process exceeded the limit for cadmium and one of them also for lead, although the composition of the charges used by the three foundries varied widely. Only 3

TABLE 5. COMPARISON OF LFE DIGESTS AA DATA WITH EMSL-LV DATA

Foundry + Sample Code	Waste Aliquot Number	LFE Data (mg/kg)			EMSL-LV Data (mg/kg)		
		Cadmium	Chromium	Lead	Cadmium	Chromium	Lead
PB6	100241	73	154	21,800	80.1	89	20,500
PD16	106861	31	69	19,000	34.0	44	19,200
PG28	107753	21	151	13,800	23.0	80	12,700
PH34	102251	72	1,770	10,500	78.6	1,183	10,300
MKK44	110841	118	1,480	6,720	132	1,525	6,120
MM52	112561	958	164	31,500	1,070	159	30,100
MN54	113251	15	71	2,650	17.7	70	2,630
MR66	117151	168	2,680	390	180	2,863	390
MS70	118761	100	135	3,480	110	130	3,350
Linear Regression							
Slope =		0.895 ±0.002	0.968 ±0.080	1.040 ±0.018			
Intercept =		1.359 ±0.937	80.6 ±92.6	31 ±265			
Corr. Coeff. =		0.9999	0.9840	0.9990			

of 15 wastes from the Venturi-type scrubbers exceeded the limit for lead (and in one case for cadmium) whereas six out of eight wastes collected with the baghouse system exceeded the limit for one or both of these elements. The extract from the waste of the MS foundry where lead-weighted wheels were noted among the scrap exceeded the limit for lead by 50 percent. However, no correlation could be found between the charges used (as reported by the foundries) and the levels of cadmium and lead in the extracts.

TABLE 6. COMPARISON OF UNIVERSITY OF WISCONSIN EXTRACTS AA DATA WITH EMSL-LV DATA

Foundry + Sample Code	Waste Aliquot Number	Wiconsin Data (mg/l)			EMSL-LV Data (mg/l)		
		Cadmium	Chromium	Lead	Cadmium	Chromium	Lead
PB6	100223	1.04	<0.07	22.6	1.082	0.07	24.0
PD16	106823	1.01	<0.07	102	0.997	0.07	116.1
PG28	107733	0.07	<0.07	8.4	0.074	0.07	7.3
PH34	102213	1.63	<0.07	11.6	1.678	0.08	11.7
MKK44	110833	1.34	<0.07	2.3	1.354	0.10	2.0
MM52	112513	1.78	<0.07	20.7	1.810	0.10	20.6
MN54	113233	0.33	<0.07	22.5	0.327	0.06	22.0
MR66	117113	2.23	0.58	<0.6	2.148	0.83	<0.05
MS70	118713	0.66	<0.07	14.0	0.661	0.12	14.3
Linear Regression							
			a	b			
Slope =		1.009 ±0.021		0.949 ±0.036			
Intercept =		-0.015 ±0.027		0.767 ±0.589			
Corr. Coeff. =		0.9985		0.9964			
QC STD	109711	16.2	ca 20	16.7	16.2	16.2	16.6
True Value =		16.0	16.0	16.0	16.0	16.0	16.0
Agreement =		101%	ca 125%	104%	101%	101%	104%

[a]Insufficient data for regression analysis
[b]Highest concentration pair (Waste PD16) not included.

TABLE 7. COMPARISON OF UNIVERSITY OF WISCONSIN DIGESTS AA DATA WITH EMSL-LV DATA

Foundry + Sample Code	Waste Aliquot Number	Wisconsin Data (mg/kg)			EMSL-LV Data (mg/kg)		
		Cadmium	Chromium	Lead	Cadmium	Chromium	Lead
PB6	100243	79	--	20,300	80.1	89	20,500
PD16	106863	32	--	18,700	34.0	44	19,200
PG28	107753	20	--	13,300	23.0	80	12,700
PH34	102253	77	--	9,900	78.6	1,183	10,300
MKK44	110843	129	--	6,400	132	1,525	6,120
MM52	112563	E	--	29,400	1,070	159	30,100
MN54	113253	16	--	2,600	17.7	70	2,630
MS70	118763	112	--	3,300	110	130	3,350
Linear Regression							
Slope =		1.013 ±0.016	--	0.970 ±0.017			
Intercept =		-2.343 ±1.278	--	302 ±291			
Corr. Coeff. =		0.9994	--	0.9992			

E indicates concentration that exceeded calibrated range.

TABLE 8. FURNACE CHARGES USED (in % of Total), AS REPORTED BY THE FOUNDRIES IN THE QUESTIONNAIRES

Foundry Code	PA	PB	PC	PD	PE	PF	PG	PH	PI	MJ	MK	MKK	ML	MM*	MN	MNN	MO	MP	MQ	MR	MS	MT	MU
Cast borings												50											
Cast iron briquet		10										1			15					25			
Gates	35	20	10	10			5	15	10		10	3.5			15	20	14.5				20		10
Own returns	35	5	10	10	55	60	5	15	11	10	10	3.5	15		15	22	14.5	40	60	45	25	25	5
Pig iron	25		35		30	20	20	15	26	50			17.5		15	37	19	10	40	25		14	25
Scrap castings		20	5	10	4		10	11			10	3.5				7	14.5				12		
Steel bushing											5	3.5								5			
Steel forgings											5	3.5											15
Steel rail		7	15			20	5																
Crankshafts											10	3.5						10					
Motorblock	1					10	30			15	10	3.5	8				14.5	10					
Crushed auto											5	3.5											
Plate steel	1	7									5	3.5			5		2	4.5				13	
Structural steel	2	7			6					25	5	3.5			5		2	4.5			16		
Punchings	1										5	3.5			5			4.5			17		
Stampings											5	3.5			5	12							
Cast iron		20		23	5		10	11	26		10	3.5	50		15		2	4.5					45
"Country" cast								11									2						
Cupola cast				23				11			5	3.5											
Machine scrap			25	23				11	26							2	14.5					48	
Other		4					15						1.5		5			12			10		
Furnace type	C	C	C	C	C	C	C	EA	C	C	C	EA	C	C	C	C	C	C	C	EA	C	C	C
Scrubber type	V	B/Q	V	B	B/Q	B/Q	V/Q	B	V	V	V/Q	B	V/Q	V/Q	V/Q	V/Q	V/Q	V	V/Q	B	B	V	V/Q
Positives		Pb,Cd		Pb			Pb	Pb,Cd				Cd		Pb,Cd		Pb				Cd	Pb		

* No information available
C = Cupola, EA = Electric Arc, V = Venturi, B = Baghouse, Q = Quencher

APPENDIX 1

QUESTIONNAIRES DISTRIBUTED TO THE GRAY IRON FOUNDRIES TO BE SAMPLED

GRAY IRON FOUNDRY STUDY: BACKGROUND INFORMATION

Name of company _____

Name of foundry visited _____

Street address _____

_____

_____

Person and mailing address for sending back reports _____

_____

_____

_____

Name of person providing information _____

Title _____

Telephone number _____

QUESTIONS

Questions	Contractor's Comments
1. a. What type of furnace(s) is(are) used to melt the furnace charge for grey iron castings? _____	
b. What other alloys or products are melted in the furnace? _____	
2. What type of air pollution control device is used on the furnace(s)? (Check appropriate answer(s) below.)	
a. _____ Dry (Baghouse): (If checked, please answer the following questions.)	
i. How is dust from the baghouse disposed of?	
_____ Landfilled as dust	
_____ Wetted down before landfilled	
_____ Mixed with plant wastewater (If checked, at what point in your flow chart?) _____	
_____ Mixed with wastewater sludge	
_____ Other. (Please specify) _____	
ii. How many pounds of emission control dust are generated per ton of metal produced? _____	
b. _____ Wet (Scrubber): (If checked, please answer the following questions.)	

Questions	Contractor's Comments
i. How is wastewater from the furnace scrubber treated:	
_____ Treated separately from other process waste streams	
_____ Treated then mixed with other process waste streams	
_____ Mixed with other process waste streams, then treated	
_____ Other. Please specify:	
_____	
_____	
_____	
ii. Type of wet scrubber (e.g., Venturi, Wet Cap)	
_____	
iii. How is the sludge from the wastewater treatment process disposed of?	
_____ Landfilled separately	
_____ Mixed with other foundry wastes, then landfilled	
_____ Other. (Please specify.)	
_____	
_____	
_____	
3. a. What type of scrap is normally used for the gray iron? (Please check any of the following which are used.)	
a. _____ Cast borings	
b. _____ Cast iron briquettes	

Questions	Contractor's Comments
c. _____ Free melts	
d. _____ Gates	
e. _____ Own returns	
f. _____ Pig iron	
g. _____ Scrap casting	
h. _____ Steel bushling	
i. _____ Steel forgings	
j. _____ Steel rail	
k. _____ Crankshafts	
l. _____ Motorblock	
m. _____ Crushed autobodies	
n. _____ Plate steel	
o. _____ Structural steel	
p. _____ Punchings	
q. _____ Stampings	
r. _____ Cast iron scrap	
s. _____ "Country Cast" (from farm machinery)	
t. _____ "Cupola Cast" (from iron scrap)	
u. _____ Machine Scrap	
_____ Other. (Please specify.)	
_____	
b. Please list the percentage used of each of the above scrap types for the last four days:	

Questions	Contractor's Comments
Day 1	
Day 2	
Day 3	

Questions	Contractor's Comments
Day 4	
4. Do you expect any of your scrap to contribute significant amounts of either cadmium, chromium, lead, zinc, tin or other nonferrous metals to your waste (i.e., emission control dusts or waste-water treatment sludges)? If so, which components and which metals?	
5. What data do you have on the chemical composition of your waste?	

With the exception of any "Contractor's Comments" above, I certify that the information I have provided above on the above-named gray iron foundry is accurate and correct to the best of my knowledge.

Signed (signature of person providing information)	Date

APPENDIX 2

SEQUENCE OF EVENTS ASSOCIATED WITH THE SAMPLING OF EACH FOUNDRY

1. Prepare chain of custody forms, EPA questionnaries, labels, envelopes.
2. Select and prepare sampling clothing and equipment.
3. Drive to sampling site.
4. Make presentation and hand questionnaire to foundry personnel. Discuss with foundry representatives what samples are to be taken. Have plant representative sign the chain-of-custody forms.
5. Don sampling clothing, select and prepare sampling equipment for transport.
6. Sampling:
   a. Decide on sampling pattern.
   b. Fill sample container (one person takes the sample, while the second person holds (and shakes) the container).
   c. Record sampling procedure, pattern (including dimensions) and miscellaneous observations in the logbook. Fill out the sample label.
   d. Wipe off the outside of the sampler container. Put the label on the container. Clean sampling equipment (at least dry wipe).
7. Repeat sampling procedure 6 at each sampling location. This usually includes taking one sample, in a one-gallon container, of dry or wet scrubber waste, and one sample, in a one-gallon container, of mixed waste.
8. Transport the closed containers back to the transport vehicle (van).
9. Remove sampling clothing. Put sampling clothing and equipment in plastic bags. Complete logbook entries.
10. Drive to freight shipping location for samples to be shipped.

11. Place chain-of-custody form and daily field logbook sheets in a sealed envelope. Place envelope in the inside on the top of the shipping box.

12. Seal caps on sample container(s) with EPA chain-of-custody tape.

13. Fill out Federal Express shipping and Tally Record Service forms.

14. Cubitainers are shipped in cardboard boxes. Liquid to semiliquid samples are shipped in wide-mouthed bottles in wooden crates containing vermiculite, and lined with a plastic bag.

List of Essential Sampling Equipment

1. 2 Hardhats
2. 2 Pairs of Boots
3. 2-3 Pairs of Coveralls
4. 2 Pairs of Goggles
5. Brush
6. Labels
7. Envelopes
8. Pens (indelible)
9. Box Wrap Tape and Chain-of-Custody Tape
10. Cubitainers (1-gallon size)
11. Glass Bottles with Lids (1-gallon size)
12. Cardboard Shipping Boxes for Cubitainers
13. Special Wooden Crates for Shipping Glass Bottles
14. Paper Towels
15. Trowel and Funnel
16. Gloves - green (powdered inside, tight) latex, and larger, opaque white
17. Plastic Bags
18. Duffle Bag

Checklist for Packing Samples for Shipment

1. Label sample container.
2. Seal lid with chain-of-custody tape.
3. Fill out chain-of-custody form and lab analysis form (or lab/field logbook).
4. Enclose forms in envelope.
5. Enclose envelope and sample in shipping container.
6. Tape container shut and label.

APPENDIX 3

SUMMARY OF ALL SAMPLES COLLECTED

Foundry Code	Field Sample Number	Scrubber System Type	Type of Waste	Description	Date Taken	Comments
PA	1*, 3**	Funnel Venturi	Solid Wet	B	7/28/80	Cupola D
PA	2*, 4**	Funnel Venturi	Solid Wet	B	7/28/80	Cupola E
PB	5***, 6*	Baghouse Preceded by Quencher	Solid Dry	C	7/29/80	Cupola
PB	7***, 8* 9***, 10**	Baghouse Preceded by Quencher	Liquid	F	7/29/80	Cupola G
PC	11***, 12* 13***, 14**	Funnel Venturi	Solid Wet	B	7/29/80	Cupola
PD	15***, 16* 17***, 18**	Baghouse	Solid Dry	H	7/30/80	Cupola
PE	19*	Baghouse Preceded by Quencher	Quencher Solid Dry	A	7/31/80	Cupola J
PE	20*, 21**	Baghouse Preceded by Quencher	Baghouse Solid Dry	C	7/31/80	Cupola J
PF	22* , 23***	Baghouse Preceded by Quencher	Quencher Solid Dry	A	7/31/80	Cupola
PF	24* , 25*** 26**, 27***	Baghouse Preceded by Quencher	Baghouse Solid Dry	C	7/31/80	Cupola
PG	28* , 29*** 30**, 31***	Venturi with Quencher	Venturi Solid Wet	B	8/01/80	Cupola K
PH	32**, 34* (#33 not collected)	Baghouse	Solid Dry	C	8/01/80	Electric Arc
PI	35***, 36* 37***, 38**	Venturi	Solid Wet	B	8/02/80	Cupola
MJ	39** , 40*	Venturi	Solid Dry	B	8/18/80	Cupola
MK	41***, 42*	Venturi with Quencher	Solid Dry	B	8/18/80	Cupola
MKK	43***, 44*	Baghouse	Solid Dry	C	8/19/80	Electric Arc
MKK	45***, 46* 47***, 48**	Venturi with Quencher	Quencher Solid Dry	A	8/18/80	Electric Arc N

(continued)

APPENDIX 3. (Continued)

Foundry Code	Field Sample Number	Scrubber System Type	Type of Waste	Description	Date Taken	Comments
ML	49**, 50*	Venturi with Quencher	Liquid	F	8/19/80	Cupola
ML	51*	Venturi with Quencher	Liquid	M	8/19/80	Cupola
MM	52* , 53**	Venturi with Quencher	Solid Wet	B	8/19/80	Cupola O
MN	54* , 55***	Venturi with Quencher	Solid Wet	B	8/20/80	Cupola (Permanent Mold Process)
MNN	56* , 57*** 58**	Venturi with Quencher	Solid Dry	B	8/20/80	Cupola (Shell Mold Process)
MO	58* , 59**	Venturi with Quencher	Solid Wet	B	8/21/80	Cupola
MP	60* , 61** 62***, 63***	Venturi	Solid Wet	A	8/25/80	Cupola K
MQ	64* , 65**	Venturi with Quencher	Solid Wet	B	8/25/80	Cupola
MR	66* , 67**	Baghouse	Solid Dry	C	8/26/80	Electric Arc
MR	68* , 69**	Baghouse	Solid Dry	C	8/26/80	Electric Arc
MS	70* , 71** 72***, 73***	Baghouse	Solid Dry	C	8/27/80	Cupola P
MT	74* , 75** 76***, 77***	Venturi	Solid Wet	B	8/28/80	Cupola
MU	78* , 79**	Venturi with Quencher	Solid Dry	B	8/28/80	Cupola

* Samples shippped to EMSL-LV.

** Mixed waste samples shipped to:
Dr. William Boyle
Dept. of Civil and Environmental Engineering
3230 Engineering Building
University of Wisconsin
Madison, WI 53706

*** Samples requested by foundry.

A Coarse pebble-sized and sand-like material, black.

B A fine black sand-like material with occasional larger particles, grit-like in texture.

C A very fine brown powder much like talc.

D From previous charge runs.

E From current charge run.

F Liquid containing black sand-like material which varies from extremely fine to BB-size particles.

G Contains more than furnace scrubber waste.

H A very fine gray powder mixed with larger pieces of slag.

I Material accumulated over 2-months time.

J Used a coagulant in the system.

K Vacuum belt system to separate water from waste.

L Waste Pond.

M Mostly slag.

N Half of sample was from quencher and half from the Venturi scrubber.

O Lead wheel weight seen on scrap.

APPENDIX 4

SAMPLE LISTING FOR THE GRAY IRON FOUNDRY PROJECT - PENNSYLVANIA

Date	Foundry Code	Sample Number		Consignee	Waste Type*	Wet (W)/ Dry (D)
7/28	PA	1		EMSL-LV	S(V)	W
7/28	PA	2		EMSL-LV	S(V)	W
7/28	PA	3		U. of Wisc.	M	D
7/28	PA	4		U. of Wisc.	M	D
7/29	PB	5	split	PB	S(B)	D
7/29	PB	6		EMSL-LV	S(B)	D
7/29	PB	7	split	PB	S†	W
7/29	PB	8		EMSL-LV	S†	W
7/29	PB	9	split	PB	M	D
7/29		10		U. of Wisc.	M	D
7/29	PC	11	split	PC	S(V)	W
7/29	PC	12		EMSL-LV	S(V)	W
7/29	PC	13	split	PC	M	D
7/29	PC	14		U. of Wisc.	M	D
7/30	PD	15	split	PD	S(B)	D
7/30	PD	16		EMSL-LV	S(B)	D
7/30	PD	17	split	PD	M	D
7/30	PD	18		U. of Wisc.	M	D

(continued)

* S = Scrubber; M = Mixed
  Q = Quencher; B = Baghouse; V = Venturi
† Cooling Liquid

APPENDIX 4. (Continued)

Date	Foundry Code	Sample Number	Consignee	Waste Type*	Wet (W)/ Dry (D)
7/31	PE	19	EMSL-LV	S(Q)	D
7/31	PE	20	EMSL-LV	S(B)	D
7/31	PE	21	U. of Wisc.	M	D
7/31	PF	22 split	EMSL-LV	S(Q)	D
7/31	PF	23	PF	S(Q)	D
7/31	PF	24 split	EMSL-LV	S(B)	D
7/31	PF	25	PF	S(B)	D
7/31	PF	26 split	U. of Wisc.	M	D
7/31	PF	27	PF	M	D
8/01	PG	28	EMSL-LV	S(Q)	W
8/01	PG	29	PG	S(Q)	W
8/01	PG	30 split	U. of Wisc.	M	D
8/01	PG	31	PG	M	D
8/01	PH	32	U. of Wisc.	M	D
8/01	PH	33	Not collected		
8/01	PH	34	EMSL-LV	S(B)	D
8/02	PI	35 split	PI	S(Q)	W
8/02	PI	36	EMSL-LV	S(Q)	W
8/02	PI	37	PI	M	D
8/02	PI	38	U. of Wisc.	M	D

* S = Scrubber; M = Mixed
  Q = Quencher; B = Baghouse; V = Venturi

APPENDIX 5

SAMPLE LISTING FOR THE GRAY IRON FOUNDRY PROJECT - MICHIGAN

Date	Foundry Code	Sample Number	Consignee	Waste Type*	Wet (W)/ Dry (D)
8/18	MJ	39	U. of Wisc.	M	D
8/18	MJ	40	EMSL-LV	S(V)	W
8/18	MK	41 split	MK	S(V)	W
	MK	42	EMSL-LV	S(V)	W
8/18	MKK	43	MK	S(B)	D
8/18	MKK	44-I split	EMSL-LV	S(B)	D
	MKK	44-II	EMSL-LV	S(B)	D
8/18	MKK	45 split	MK	S(Q)	D
	MKK	46	EMSL-LV	S(Q)	D
8/18	MKK	47 split	MK	M	D
	MKK	48	U. of Wisc.	M	D
8/19	ML	49	U. of Wisc.	M	D(slag)
8/19	ML	50	EMSL-LV	S(V)	†(sluice water)
8/19	ML	51	EMSL-LV	S/M	†(pond water)
8/19	MM	52	EMSL-LV	S(V)	W
8/19	MM	53	U. of Wisc.	M	D

(continued)

* S = Scrubber; M = Mixed
Q = Quencher; B = Baghouse; V = Venturi
I = Part I of baghouse sample; II = Part II of baghouse sample.
† Liquid

APPENDIX 5. (Continued)

Date	Foundry Code	Sample Number	Consignee	Waste Type*	Wet (W)/ Dry (D)
8/20	MN	54 split	EMSL-LV	S(V)	W
	MN	55	MN	S(V)	W
8/20	MNN	56 split	EMSL-LV	S(V)	W
	MNN	57	MNN	S(V)	W
8/20	MNN	58	U. of Wisc.	M	W
8/21	MO	58-2-S	EMSL-LV	S(V)	W
8/21	MO	59	U. of Wisc.	M	D
8/25	MP	60	EMSL-LV	S(V)	W
8/25	MP	61	U. of Wisc.	M	W
8/25	MP	62 (split of 60)	MP	S(V)	W
8/25	MP	63 (split of 61)	MP	M	W
8/25	MQ	64	EMSL-LV	S(V)	W
8/25	MQ	65	U. of Wisc.	M	D
8/26	MR	66-I	EMSL-LV	S(B#2)	D
8/26	MR	66-II	EMSL-LV	S(B#2)	D
8/26	MR	67	U. of Wisc.	M(B#2)	D
8/26	MR	68-I	EMSL-LV	S(B#3)	D
8/26	MR	68-II	EMSL-LV	S(B#3)	D
8/26	MR	69	U. of Wisc.	M(B#3)	D

(continued)

* S = Scrubber; M = Mixed
Q = Quencher; B = Baghouse; V = Venturi
I = Part I of baghouse sample; II = Part II of baghouse sample.
58-2-S = Second sample #58 (scrubber waste)

APPENDIX 5. (Continued)

Date	Foundry Code	Sample Number	Consignee	Waste Type*	Wet (W)/ Dry (D)
8/27	MS	70-I	EMSL-LV	S(B)	D
8/27	MS	70-II	EMSL-LV	S(B)	D
8/27	MS	71	U. of Wisc.	M	D
8/27	MS	72 (splits	MS	S(B)	D
		73 of 70	MS	M	D
		and 71)			
8/28	MT	74	EMSL-LV	S(V)	W
8/28	MT	75	U. of Wisc.	M	D
8/28	MT	76 (split of 74)	MT	S(V)	W
8/28	MT	77 (split of 75)	MT	M	D
8/28	MU	78	EMSL-LV	S(V)	W
8/28	MU	79	U. of Wisc.	M	D

* S = Scrubber; M = Mixed
Q = Quencher; B= Baghouse; V = Venturi
I = Part I of baghouse sample; II = Part II of baghouse sample.

APPENDIX 6

RECOMMENDATIONS FOR FUTURE SAMPLING TRIPS

1. Prior to the sampling it should be determined who will be authorized to receive the samples. The samples should be relinquished from the field samples to a Federal Express representative, and Federal Express would then relinquish the samples to the consignee specified on the SSS Tally Record. All shipping boxes should be labeled with date and sample number.

2. Wide-mouth, pre-tested plastic containers should be used for scrubber or composite samples, and new gallon-tin-cans lined with four layers of plastic bags for composite samples (not when organics are to be determined!).

3. Sufficient changes of suitable company-provided clothing should be brought along and time allowed for cleaning to enable samplers to wear clean clothing to each new sample location, especially for hazardous sample collection.

4. The rented vehicle should be easy to clean, and efforts should be made in planning to prevent the vehicle from becoming unreasonably dirty as a result of sampling activities.

5. Disposable high-quality face masks and Teflon-coated sample scoops should be used when sampling hazardous waste.

6. Provisions should be made before leaving on a sampling trip to insure availability of adequate replacement sites in case some sites can not be sampled. Communications about cancellations of site visits should be swiftly relayed to sampling and support personnel.

7. The way observation on pH and scrap descriptions are recorded by the samplers should be formalized and generally agreed to by the EPA and industry before sampling. Permission to take pictures of the scrap pile should be secured.

8. Enough address labels should be typed before the trip to label all sample boxes except those that will be labeled with the Federal Express shipping packet. In addition, Federal Express shipping and SSS Tally forms should be prepared in advance as much as possible.

9. Duffle-type bags should be used to conveniently transport sample equipment and containers into and around foundries.

10. A visual distance indicator could be used to estimate pile and waste site dimensions.

11. Foundry representatives should be asked the following technical questions before the sampling trip starts:

    a. Do you have a wet cap or quencher system? Do you operate these parts of your system wet or dry? How often do you melt? How often do you dump your scrubber waste?

    b. What is the source(s) of the waste we sample? When was the waste last dumped or removed, and how much, if any, is left?

    c. What materials are composited (combined) with the scrubber waste before, or when, the scrubber waste is disposed? What is the typical ratio of materials in the combination? Exactly how is the compositing performed?

    d. Does your plant have true (unleached) composite waste (i.e., scrubber plus other waste) available for sampling? How is it disposed (especially, from where, how much at a time, and how frequently)?

    e. Is any of your waste stored in a pond as the first total composite location before disposal (i.e., will we have to use the pond sampler)?

    f. Is the waste stored in a barrel or large tank with only a single, bunghole opening?

APPENDIX 7

ALIQUOTS PREPARED, ALIQUOT RECIPIENTS AND SHIPPING DATES

Field Sample Number	Aliquot Number	Aliquot Weight (g)	Disposition and Shipping Date
PA 1	1085	713	NSI, 8/7/80
	1086	738	Univ. of Wisconsin, 8/12/80
	1087	757	Univ. of Wisconsin, 10/23/80
	1088	794	Sample Bank
	1089	677	Sample Bank
	1090	549	Sample Bank
PA 2	1053	693	NSI, 8/7/80
	1054	605	Univ. of Wisconsin, 8/12/80
	1055	639	Sample Bank
	1056	622	Sample Bank
	1057	737	Sample Bank
	1058	563	Sample Bank
PB 6	1001	450	Univ. of Wisconsin, 10/15/80
	1002	452	NSI, 8/6/80
	1003	450	Univ. of Wisconsin, 8/12/80
	1004	518	EMSL-LV, 11/17/80
PB 8	1005	500	Sample Bank
	1006	500	NSI, 8/6/80
	1007	500	Sample Bank
	1008	500	Sample Bank
	1009	500	Sample Bank
	1010	500	Univ. of Wisconsin, 8/12/80
	1011	457	Sample Bank
PC 12	1035	552	NSI, 8/7/80
	1036	581	Univ. of Wisconsin, 8/12/80
	1037	632	LFE, 8/12/80
	1038	676	Sample Bank

(continued)

APPENDIX 7. (Continued)

Field Sample Number	Aliquot Number	Aliquot Weight (g)	Disposition and Shipping Date
PC 12 (continued)	1039	667	Sample Bank
	1040	641	Sample Bank
	1041	848	Univ. of Wisconsin, 8/12/80
	1042	714	NSI, 8/12/80
	1043	624	LFE, 8/12/80
	1044	361	Sample Bank
PD 16	1068	545	NSI, 8/7/80
	1069	519	Univ. of Wisconsin, 8/12/80
	1070	505	LFE, 8/12/80
	1071	506	Univ. of Wisconsin, 10/15/80
	1072	560	Univ. of Wisconsin, 10/15/80
	1073	513	Univ. of Wisconsin, 8/12/80
	1074	557	LFE, 8/12/80
	1075	535	NSI, 8/12/80
	1076	190	EMSL-LV, 11/17/80
PE 19	1027	450	NSI, 8/7/80
	1028	450	Univ. of Wisconsin, 8/12/80
	1029	450	LFE, 8/12/80
	1030	450	Univ. of Wisconsin, 10/15/80
	1031	450	Univ. of Wisconsin, 10/15/80
	1032	450	Univ. of Wisconsin, 8/12/80
	1033	450	NSI, 8/12/80
	1034	417	LFE, 8/12/80
PE 20	1064	531	NSI, 8/7/80
	1065	513	Univ. of Wisconsin, 8/12/80
	1066	525	Univ. of Wisconsin, 10/15/80
	1067	387	Sample Bank
PF 22	1045	472	NSI, 8/7/80
	1046	499	Univ. of Wisconsin, 8/12/80
	1047	551	Univ. of Wisconsin, 10/15/80
	1048	510	Sample Bank
	1049	566	Sample Bank
	1050	517	Sample Bank
	1051	513	Sample Bank
	1052	426	Sample Bank
PF 24	1059	600	NSI, 8/7/80
	1060	507	Univ. of Wisconsin, 8/12/80
	1061	508	Univ. of Wisconsin, 10/15/80
	1062	451	Sample Bank
	1063	424	Sample Bank

(continued)

APPENDIX 7. (Continued)

Field Sample Number	Aliquot Number	Aliquot Weight (g)	Disposition and Shipping Date
PG 28	1077	720	NSI, 8/7/80
	1078	729	Univ. of Wisconsin, 8/12/80
	1079	735	Sample Bank
	1080	730	Sample Bank
	1081	680	EMSL-LV, 11/17/80
	1082	802	Sample Bank
	1083	687	Sample Bank
	1084	714	Sample Bank
PH 34	1022	453	NSI, 8/7/80
	1023	458	EMSL-LV, 11/17/80
	1024	466	Univ. of Wisconsin, 8/12/80
	1025	482	Univ. of Wisconsin, 10/15/80
	1026	352	Sample Bank
PI 36	1012	561	Sample Bank
	1013	608	Sample Bank
	1014	574	Univ. of Wisconsin, 8/12/80
	1015	597	Sample Bank
	1016	573	NSI, 8/6/80
	1017	577	Sample Bank
	1018	611	Univ. of Wisconsin, 10/23/80
	1019	590	Sample Bank
	1020	580	Sample Bank
	1021	480	Sample Bank
MJ 40	1101	490	NSI, 9/23/80
	1102	485	Univ. of Wisconsin, 9/25/80
	1103	545	LFE, 9/25/80
	1104	550	Univ. of Wisconsin, 10/15/80
	1105	470	Sample Bank
	1106	505	Sample Bank
	1107	690	Sample Bank
MK 42	1211	650	NSI, 9/25/80
	1212	540	Univ. of Wisconsin, 9/25/80
	1213	690	LFE, 9/25/80
	1214	660	Sample Bank
	1215	580	Sample Bank
	1216	710	Sample Bank
	1217	730	Sample Bank

(continued)

APPENDIX 7. (Continued)

Field Sample Number	Aliquot Number	Aliquot Weight (g)	Disposition and Shipping Date
MKK 44	1108	450	NSI, 9/23/80
	1109	465	Univ. of Wisconsin, 9/25/80
	1110	460	*LFE, 9/25/80
	1111	465	Univ. of Wisconsin, 10/15/80
	1112	450	EMSL-LV, 11/17/80
	1113	465	Sample Bank
	1114	510	Sample Bank
MKK 46	1115	460	NSI, 9/23/80
	1116	460	Univ. of Wisconsin, 9/25/80
	1117	505	*LFE, 9/25/80
	1118	475	Univ. of Wisconsin, 9/25/80
	1119	470	LFE, 9/25/80
	1120	465	Univ. of Wisconsin, 10/15/80
	1121	455	Sample Bank
	1122	595	NSI, 9/23/80
ML 50	1123	3770	Sample Bank (as extract)
	11231	200	NSI, 10/23/80
ML 51	1124	3300	Sample Bank
	11241	200	NSI, 10/23/80
MM 52	1125	694	NSI, 9/23/80
	1126	761	Univ. of Wisconsin, 9/25/80
	1127	739	*LFE , 9/25/80
	1128	706	Sample Bank
	1129	806	Sample Bank
	1130	711	EMSL-LV, 11/17/80
	1131	806	Sample Bank
MN 54	1132	675	NSI, 9/23/80
	1133	720	Univ. of Wisconsin, 9/25/80
	1134	800	*LFE, 9/25/80
	1135	810	EMSL-LV, 11/17/80
	1136	648	Sample Bank
	1137	730	Univ. of Wisconsin, 9/25/80
	1138	763	*LFE, 9/25/80
	1139	861	NSI, 9/23/80
MNN 56	1140	780	NSI, 9/23/80
	1141	780	Univ. of Wisconsin, 9/25/80
	1142	820	*LFE, 9/25/80
	1143	750	Sample Bank

(continued)

* Sample not analyzed

APPENDIX 7. (Continued)

Field Sample Number	Aliquot Number	Aliquot Weight (g)	Disposition and Shipping Date
MN 56 (continued)	1144	820	Sample Bank
	1145	834	Univ. of Wisconsin, 9/25/80
	1146	890	LFE, 9/25/80
	1147	840	NSI, 9/23/80
MO 58	1148	840	NSI, 9/23/80
	1149	709	Univ. of Wisconsin, 9/25/80
	1150	751	*LFE, 9/25/80
	1151	819	Sample Bank
	1152	777	Sample Bank
	1153	788	Sample Bank
	1154	819	Sample Bank
	1155	788	Sample Bank
MP 60	1156	720	NSI, 9/25/80
	1157	780	Univ. of Wisconsin, 9/25/80
	1158	750	*LFE, 9/25/80
	1159	850	Sample Bank
	1160	730	Sample Bank
	1161	818	Sample Bank
	1162	730	Sample Bank
	1163	872	Sample Bank
MQ 64	1164	861	NSI, 9/25/80
	1165	965	Univ. of Wisconsin, 9/25/80
	1166	810	*LFE, 9/25/80
	1167	790	Sample Bank
	1168	875	Sample Bank
	1169	885	Sample Bank
	1170	815	Sample Bank
MR 66	1171	580	NSI, 9/25/80
	1172	570	Univ. of Wisconsin, 9/25/80
	1173	495	*LFE, 9/25/80
	1174	460	Univ. of Wisconsin, 10/15/80
	1175	470	Univ. of Wisconsin, 10/15/80
	1176	480	Univ. of Wisconsin, 9/25/80
	1177	470	LFE, 9/25/80
	1178	520	NSI, 9/25/80

(continued)

* Sample not analyzed

APPENDIX 7. (Continued)

Field Sample Number	Aliquot Number	Aliquot Weight (g)	Disposition and Shipping Date
MK 68	1179	620	NSI, 9/25/80
	1180	610	Univ. of Wisconsin, 9/25/80
	1181	660	*LFE, 9/25/80
	1182	575	Univ. of Wisconsin, 10/15/80
	1183	600	Univ. of Wisconsin, 10/15/80
	1184	535	Univ. of Wisconsin, 9/25/80
	1185	710	*LFE, 9/25/80
	1186	560	NSI, 9/25/80
MS 70	1187	600	NSI, 9/25/80
	1188	600	Univ. of Wisconsin, 9/25/80
	1189	570	*LFE, 9/25/80
	1190	550	Univ. of Wisconsin, 10/15/80
	1191	560	Sample Bank
	1192	580	Sample Bank
	1193	620	EMSL-LV, 11/17/80
	1194	735	Sample Bank
MT 74	1195	790	NSI, 9/25/80
	1196	760	Univ. of Wisconsin, 9/25/80
	1197	805	*LFE, 9/25/80
	1198	820	Sample Bank
	1199	850	Sample Bank
	1200	810	Sample Bank
	1201	770	Sample Bank
	1202	820	Sample Bank
MU 78	1203	490	NSI, 9/25/80
	1204	600	Univ. of Wisconsin, 9/25/80
	1205	495	LFE, 9/25/80
	1206	575	Sample Bank
	1207	805	Sample Bank
	1208	755	Sample Bank
	1209	655	Sample Bank
	1210	645	Sample Bank

* Sample not analyzed

APPENDIX 8

LIST OF EXTRACTS AND DIGESTS SHIPPED TO LFE AND THE UNIVERSITY OF WISCONSIN

Extracts shipped to LFE:

# 10682A	10773A	11083A
10022A	11711A	11251A
109712[1]	11323A	
10221A	11871A	

Digest shipped to LFE:

# 100241	106861	113251
102251	118761	117151
107753	112561	110841

Extracts shipped to the University of Wisconsin:

# 100223	109713[1]	117113
102213	110833	118713
106823	112513	
107733	113233	

Digests shipped to the University of Wisconsin:

# 100243	107753	113253
102253	110843	117153
106863	112563	118763

[1] Simulated Extracts

APPENDIX 9

Section 7.0

EXTRACTION PROCEDURE TOXICITY

Introduction

The Extraction Procedure (EP) is designed to simulate the leaching a waste will undergo if disposed of in an improperly designed sanitary landfill. It is a laboratory test in which a representative sample of a waste is extracted with distilled water maintained at pH = 5 using acetic acid. The extract obtained from the EP (the "EP Extract") is then analyzed to determine if any of the thresholds established for the 8 elements (i.e., arsenic, barium, cadmium, chromium, lead, mercury, selenium, silver), four pesticides (i.e., Endrin, Lindane, Methoxychlor, Toxaphene), and two herbicides (i.e., 2,4,5-Trichlorophenoxypropionic acid, 2,4-Dichlorophenoxyacetic acid) have been exceeded. If the EP Extract contains any one of the above substances in an amount equal to or exceeding the levels specified in 40 CFR 261.24, the waste possesses the characteristic of Extraction Procedure Toxicity and is a hazardous waste.

The Extraction Procedure consists of 5 steps:

1. Separation Procedure

A waste containing unbound liquid is filtered and if the solid phase is less than 0.5% of the waste, the solid phase is discarded and the filtrate analyzed for trace elements, pesticides, and herbicides (step 5). If the waste contains more than 0.5% solids, the solid phase is extracted and the liquid phase stored for later use.

2. Structural Integrity Procedure/Particle Size Reduction

Prior to extraction, the solid material must either pass through a 9.5 mm (0.375 in) standard sieve, have a surface area per gram of waste of 3.1 cm^2, or if it consists of a single piece, be subjected to the Structural Integrity Procedure. The Structural Integrity Procedure is used to demonstrate the ability of the waste to remain intact after disposal. If the waste does not meet one of these conditions it must be ground to pass the 9.5 mm sieve.

3. Extraction of Solid Material

The solid material for step 2 is extracted for 24 hours in an aqueous medium whose pH is maintained at or below 5, using 0.5 N acetic acid. The pH is maintained either automatically or manually. Acidification to pH 5 is subject to a specification as to total amount of acid to be added to the system.

4. Final Separation of the Extraction Liquid from the Remaining Solid

After extraction, the liquid:solid ratio is adjusted to 20:1 and the mixture of solid and extraction liquid is separated by filtration, the solid discarded and the liquid combined with the filtrate obtained in step 1. This is the EP Extract that is subjected to the evaluation requirements in 40 CFR 261.24.

5. Testing (Analysis) of EP Extract

Inorganic and organic species are identified and quantified using the appropriate methods in Section 8 of this manual.

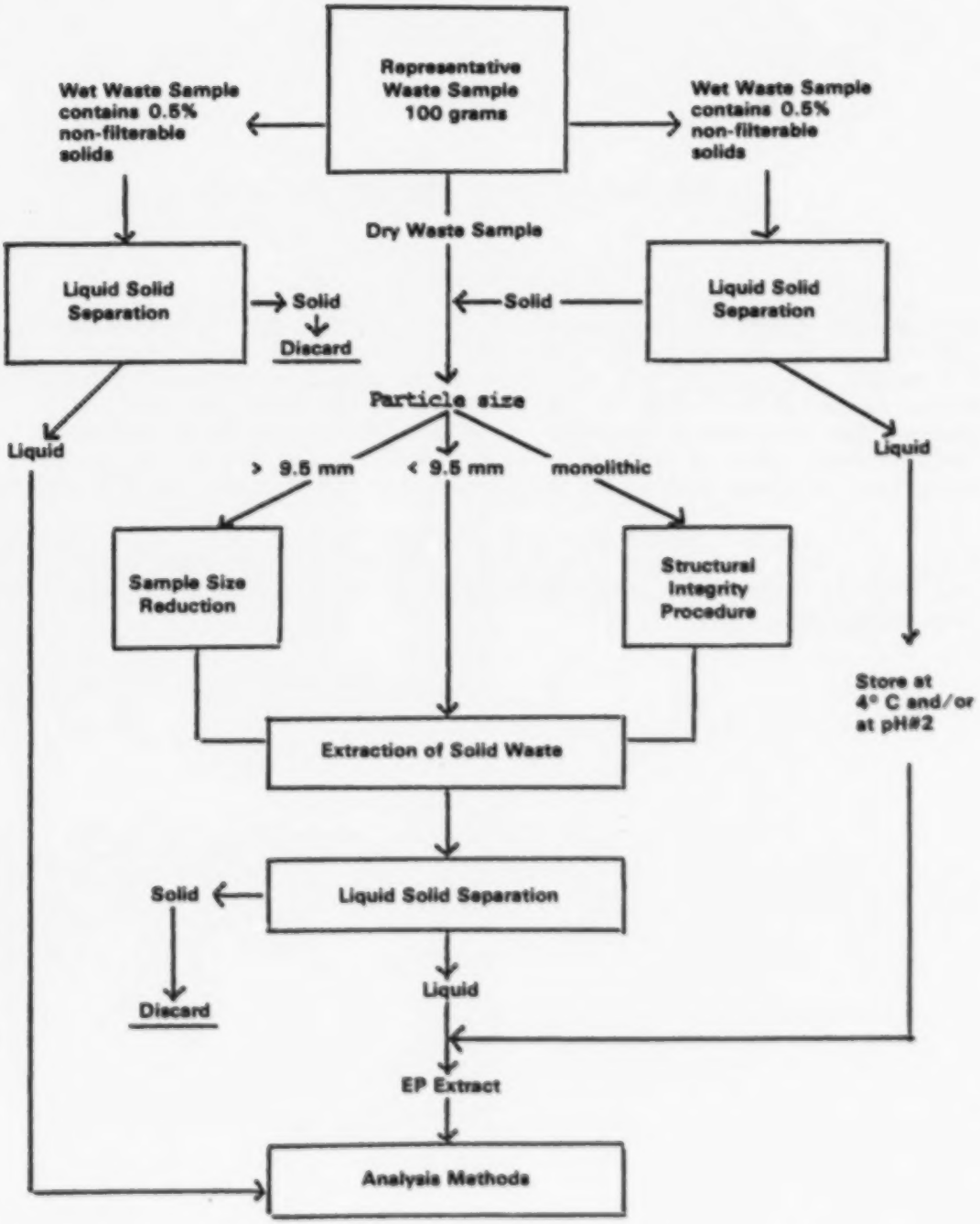

Figure 7.0. Extraction Procedure Flowchart

SUB-SECTION 7.1

CHARACTERISTIC OF EP TOXICITY REGULATION

A solid waste exhibits the characteristic of EP toxicity if, using the test methods described in Appendix II of 40 CFR Part 261 or equivalent methods approved by the Administrator under the procedures set forth in 40 CFR 260.20 and 260.21, the extract from a representative sample of the waste contains any of the contaminants listed in Table 7.1-1 at a concentration equal to or greater than the respective value given in that table. Where the waste contains less than 0.5 percent filterable solids, the waste itself, after filtering, is considered to be the extract for the purposes of this section.

A solid waste that exhibits the characteristic of EP toxicity, but is not listed as a hazardous waste in Subpart D, has the EPA Hazardous Waste Number specified in Table 7.1-1 which corresponds to the toxic contaminant causing it to be hazardous.

TABLE 7.1-1. MAXIMUM CONCENTRATION OF CONTAMINANTS FOR CHARACTERISTIC OF EP TOXICITY

EPA Hazardous Waste Number	Contaminant	Maximum Concentration (milligrams per liter)
D004	Arsenic	5.0
D005	Barium	100.0
D006	Cadmium	1.0
D007	Chromium	5.0
D008	Lead	5.0
D009	Mercury	0.2
D010	Selenium	1.0
D011	Silver	5.0
D012	Endrin (1,2,3,4,10,10-Hexachloro-1-7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1-4-endo, endo-5,8-dimethanonaphthalene)	0.02
D013	Lindane (1,2,3,4,5,6-Hexachlorocyclohexane, gamma isomer)	0.4
D014	Methoxychlor (1,1,1-Trichloro-2,2-bis-[p-methoxyphenyl]ethane)	10.0
D015	Toxaphene ($C_{10}H_{10}Cl_8$, Technical chlorinated camphene, 67-69 percent chlorine)	0.5
D016	2,4-D (2,4-Dichlorophenoxyacetic acid)	10.0
D017	2,4,5-TP [Silvex] (2,4,5-Trichlorophenoxypropionic acid)	1.0

APPENDIX II

EP TOXICITY TEST

Procedure

1. A representative sample of the waste to be tested (minimum size 100 grams) should be obtained using the methods specified in Appendix I of 40 CFR 261 or any other method capable of yielding a representative sample within the meaning of 40 CFR 260.

2. The sample should be separated into its component liquid and solid phases using the method described in "Separation Procedure" below. If the dry weight of the solid residue* obtained using this method totals less than 0.5% of the original wet weight of the waste, the residue can be discarded and the operator should treat the liquid phase as the extract and proceed immediately to Step 8.

3. The solid material obtained from the Separation Procedure should be evaluated for its particle size. If the solid material has a surface area per gram of material equal to, or greater than, 3.1 cm^2 or passes through a 9.5 mm (0.375 inch) standard sieve, the operator should proceed to Step 4. If the surface area is smaller or the particle size larger than specified above, the solid material would be prepared for extraction by crushing, cutting or grinding the material so that is passes through a 9.5 mm (0.375 inch) sieve or, if the material is in a single piece, by subjecting the material to the "Structural Integrity Procedure" described below.

4. The solid material obtained in Step 3 should be weighed immediately and placed in an extractor with 16 times its weight of deionized water. Do not allow the material to dry prior to weighing. For purposes of this test, an acceptable extractor is one which will impart sufficient agitation to the mixture to not only prevent stratification of the sample and extraction fluid but also insure that all sample surfaces are continuously brought into contact with well-mixed extraction fluid.

* The percent solids is determined by drying the filter pad at 80°C until it reaches constant weight and then calculating the percent solids using the following equation:

$$\frac{\text{(weight of pad + solid) - (tare weight of pad)}}{\text{initial wet weight of sample}} \times 100 = \% \text{ solids}$$

5. After the solid material and deionized water are placed in the extractor, the operator should begin agitation and measure the pH of the solution in the extractor. If the pH is greater than 5.0, the pH of the solution should be decreased to 5.0 ± 0.2 by adding 0.5 N acetic acid. If the pH is equal to or less than 5.0, no acetic acid should be added. The pH of the solution should be monitored, as described below, during the course of the extraction and if the pH rises above 5.2, 0.5N acetic acid should be added to bring the pH down to 5.0 ± 0.2. However, in no event shall the aggregate amount of acid added to the solution exceed 4 ml of acid per gram of solid. The mixture should be agitated for 24 hours and maintained at 20°-40°C (68°-104°F) during this time. It is recommended that the operator monitor and adjust the pH during the course of the extraction with a device such as the Type 45-A pH Controller manufactured by Chemtrix, Inc., Hillsboro, Oregon 97123 or its equivalent, in conjunction with a metering pump and reservoir of 0.5N acetic acid. If such a system is not available, the following manual procedure shall be employed:

   a. A pH meter should be calibrated in accordance with the manufacturer's specifications.

   b. The pH of the solution should be checked and, if necessary, 0.5N acetic acid should be manually added to the extractor until the pH reaches 5.0 ± 0.2. The pH of the solution should be adjusted at 15, 30, and 60 minute intervals, moving to the next longer interval if the pH does not have to be adjusted more than 0.5 pH units.

   c. The adjustment procedure should be continued for at least 6 hours.

   d. If at the end of the 24-hour extraction period, the pH of the solution is not below 5.2 and the maximum amount of acid (4 ml per gram of solids) has not been added, the pH should be adjusted to 5.0 ± 0.2 and the extraction continued for an additional four hours, during which the pH should be adjusted at one hour intervals.

6. At the end of the 24-hour extraction period, deionized water should be added to the extractor in an amount determined by the following equation

$$V = (20)(W) - 16(W) - A$$

   V = ml deionized water to be added

   W = Weight in grams of solid charged to extractor

   A = ml of 0.5N acetic acid added during extraction.

7. The material in the extractor should be separated into its component liquid and solid phases as described under "Separation Procedure."

8. The liquids resulting from Steps 2 and 7 should be combined. This combined liquid (or the waste itself if it has less than 0.5% solids, as noted in step 2) is the extract and should be analyzed for the presence of any of the contaminants specified in Table I of 40 CFR 261.24 using the Analytical Procedures designated below.

Separation Procedure

Apparatus

A filter holder, designed for filtration media having a nominal pore size of 0.45 micrometer and capable of applying a 5.3 kg/cm^2 (75 psig) hydrostatic pressure to the solution being filtered shall be used. For mixtures containing non-absorptive solids, where separation can be effected without imposing a 5.3 kg/cm^2 pressure differential, vacuum filters employing a 0.45 micrometer filter media can be used.

Procedure*

1. Following manufacturer's directions, the filter unit should be assembled with a filter bed consisting of a 0.45 micrometer filter membrane. For difficult or slow-to-filter mixtures a prefilter bed consisting of the following prefilters in increasing pore size (0.65 micrometer membrane, fine glass fiber prefilter, and coarse glass fiber prefilter) can be used.

2. The waste should be poured into the filtration unit.

3. The reservoir should be slowly pressurized until liquid begins to flow from the filtrate outlet at which point the pressure in the filter should be immediately lowered to 10-15 psig. Filtration should be continued until liquid flow ceases.

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* This procedure is intended to result in separation of the "free" liquid portion of the waste from any solid matter having a particle size >0.45um. If the sample will not filter, various other separation techniques can be used to aid in the filtration. As described above, pressure filtration is employed to speed up the filtration process. This does not alter the nature of the separation. If liquid does not separate during filtration, the waste can be centrifuged. If separation occurs during centrifugation, the liquid portion (centrifugate) is filtered through the 0.45um filter prior to becoming mixed with the liquid portion of the waste obtained from the initial filtration. Any material that will not pass through the filter after centrifugation is considered a solid and is extracted.

4. The pressure should be increased stepwise in 10 psig increments to 75 psig and filtration continued until flow ceases or the pressurizing gas begins to exit from the filtrate outlet.

5. The filter unit should be depressurized, the solid material removed and weighed and then transferred to the extraction apparatus, or, in the case of final filtration prior to analysis, discarded. If the solid is to be extracted do not allow the material retained on the filter pad to dry prior to weighing.

6. The liquid phase should be stored at 4°C for subsequent use in Step 8.

Structural Integrity Procedure

Apparatus

A Structural Integrity Tester having a 3.18 cm (1.25 in.) diameter hammer weighing 0.33 kg (0.73 lbs.) and having a free fall of 15.24 cm (6 in.) shall be used. This device is available from Associated Design and Manufacturing Company, Alexandria, VA, 22314, as Part No. 125, or it may be fabricated to meet the specifications shown in Figure 7-2.

Procedure

1. The sample holder should be filled with the material to be tested. If the sample of waste is a large monolithic block, a portion should be cut from the block having the dimensions of a 3.3 cm (1.3 in.) diameter x 7.1 cm (2.8 in.) long cylinder. For a fixated waste, samples may be cast in the form of a 3.3 cm (1.3 in.) diameter x 7.1 cm (2.8 in.) cylinder for purposes of conducting this test. In such cases, the waste may be allowed to cure for 30 days prior to further testing.

2. The sample should be placed into the Structural Integrity Tester, then the hammer should be raised to its maximum height and dropped. This should be repeated fifteen times.

3. The material should be removed from the sample holder, weighed, and transferred to the extraction apparatus for extraction.

Procedures for Analyzing Extract

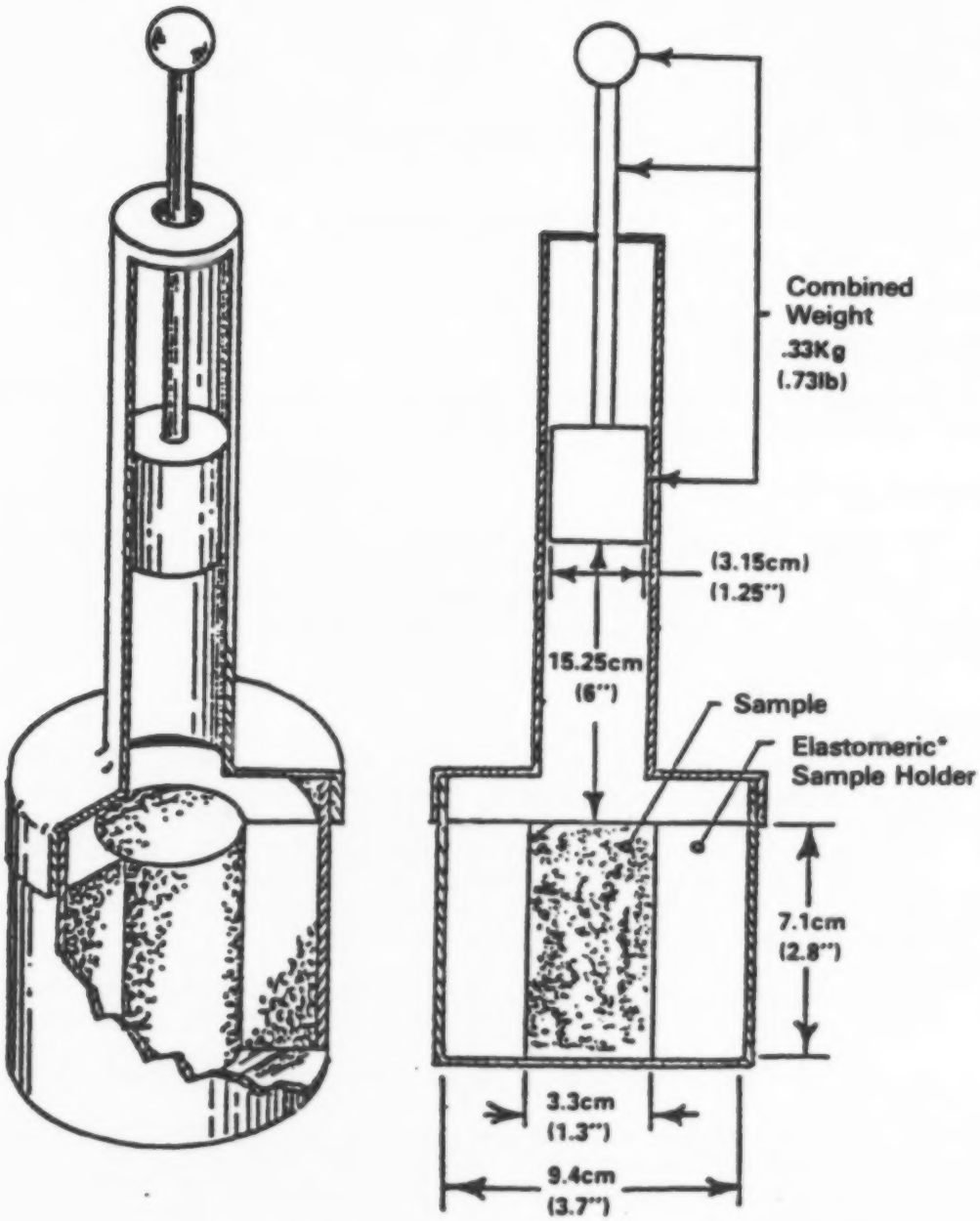
The test methods for analyzing the extract are as follows:

1. For arsenic, barium, cadmium, chromium, lead, mercury, selenium or silver: "Methods for Analysis of Water and Wastes," Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268 (EPA-600/4-79-020, March 1979).

2. For Endrin; Lindane; Methoxychlor; Toxaphene; 2,4-D; 2,4,5-TP (Silvex): in "Methods for Benzidine, Chlorinated Organic Compounds, Pentachloro-

phenol and Pesticides in Water and Wastewater," September 1978, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268. As standardized in "Test Methods for the Evaluation of Solid Waste, Physical/Chemical Methods."

For all analyses, the method of standard addition shall be used for the quantification of species concentration. This method is described in "Test Methods for the Evaluation of Solid Waste." (It is also described in "Methods for Analysis of Water and Wastes.")



*Elastomeric Sample Holder Fabricated of Material Firm Enough to Support the Sample

Figure 7.2. Compaction Tester

Method 7.2

SEPARATION PROCEDURE

Scope and Application

This procedure is used to separate a waste into its liquid and solid phases both prior to and after extraction.

Summary of Method

The Separation Procedure involves vacuum or pressure filtration of a waste or extraction mixture. To minimize filtration time, pressure, settling, centrifugation and prefilters may be employed as an adjunct to filtration. Pressure filtration is required when vacuum filtration is inadequate for complete separation.

Apparatus

1. Filter holder: A filter holder capable of supporting a 0.45 um filter membrane and able to withstand the pressure needed to accomplish separation. Suitable filter holders range from simple vacuum units to relatively complex systems that can exert up to 5.3 kg/cm^2 (75 psi) of pressure. The type of filter holder used depends upon the properties of the mixture to be filtered. Filter holders known to the Agency and deemed suitable for use are listed in Table 7.2-1.

2. Filter membrane: Filter membrane suitable for conducting the required filtration shall be fabricated from a material which:

   a. is not physically changed by the waste material to be filtered.

   b. does not absorb or leach the chemical species for which a waste's EP Extract will be analyzed. Table 7.2-2 lists filter media known to the Agency and generally found to be suitable for solid waste testing.

3. In cases of doubt contact the filter manufacturer to determine if either membrane or prefilter are adversely affected by the particular waste. If no information is available, submerge the filter in the waste's liquid phase. After 48 hours a filter that undergoes visible physical change (i.e., curls, dissolves, shrinks, or swells) is unsuitable for use.

Use the following procedure to establish if a filter membrane will leach or adsorb chemical species.

a. Prepare a standard solution of the chemical species of interest.

b. Analyze the standard for its concentration of the chemical species.

c. Filter the standard and re-analyze. If the concentration of the filtrate differs from the original standard, the filter membrane leaches or absorbs one or more of the chemical species.

General Procedure

1. Weigh filter membrane and prefilter to ± 0.01 gram. Handle membrane and prefilters with blunt curved tip forceps or vacuum tweezers, or by applying suction with a pipette.

2. Assemble filter holder, membranes, and prefilters following the manufacturer's instructions. Place the 0.45 um membrane on the support screen and add prefilters in ascending order of pore size. Do no pre-wet filter membrane.

3. Allow slurries to stand to permit the solid phase to settle. Slow to settle wastes may be centrifuged prior to filtration.

4. Wet the filter with a small portion of the waste's or extraction mixture's liquid phase. Transfer the remaining material to the filter holder and apply vacuum or gentle pressure (10-15 psi) until all liquid passes through the filter. Stop filtration when air or pressurizing gas moves through the membrane. If this point is not reached under vacuum or gentle pressure slowly increase the pressure in 10 psi increments to 75 psi. Halt filtration when liquid flow stops.

5. Remove solid phase and filter media and weigh to ± 0.01 gram. Discard solid if it comprises less than 0.5% of the mixture (see below). If the sample contains >0.5% solids use the wet weight of the solid phase obtained in this separation for purposes of calculating amount of liquid and acid to employ for extraction using the following equation:

$$W = W_f - W_t$$

W = wet weight in grams of solid to be charged to extractor

W_f = wet weight in grams of filtered solids and filter media

W_t = weight in grams of tared filters.

Procedure for Determining Percent Solids of a Waste

1. Determine percent solids of a waste sample by:

a. separately weighing the waste sample and filters.

b. filtering the waste material.

c. drying the solid and filters at 80°C until two successive weighings yield the same value. Calculate the percent solids using the following equation:

$$\frac{\text{weight of filtered solid and filters - tared weight of filters}}{\text{initial weight of waste material}} \times 100 = \% \text{ solids}$$

NOTE: This procedure is only used to determine if the solid must be extracted or if it can be discarded unextracted. It is not used in calculating the amount of water or acid to use in the extraction step. Do not extract solid material that has been dried at 80°C. A new sample will have to be used for extraction if a % solids determination is performed.

TABLE 7.2-1

APPROVED FILTER HOLDERS

Manufacturer	Size	Model Number	Comments
Vacuum Filters			
Nalgene	500 ml	45-0045	Disposable plastic unit, includes prefilter and filter pads, and reservoir. Should only be used when solution is to be analyzed for inorganic constituents.
Nuclepore	47 mm	410400	
Millipore	47 mm	XX10 047 00	
Pressure Filters			
Nuclepore	142 mm	420800	
Micro Filtration Systems	142 mm	302300	
Millipore	142 mm	YT30 142 HW	

TABLE 7.2-2

APPROVED FILTRATION MEDIA

Filter Type	Supplier	Filter To Be Used For Aqueous Systems	Filter To Be Used For Organic Systems
Coarse Prefilter	Gelman	61653 61669	61652 61669
	Nuclepore	210907 211707	210907 211707
	Millipore	AP25 042 00 AP25 127 50	AP25 042 00 AP25 127 00
Medium Prefilters	Nuclepore	21095 211705	21095 211705
	Millipore	AP20 042 00 AP20 124 50	AP20 042 00 AP20 124 50
Fine Prefilters	Nuclepore	210903 211703	210903 211703
	Millipore	AP25 042 00 AP25 127 50	AP25 042 00 AP25 127 50
Fine Filters (0.45um)	Gelman	60173 60177	60540 60544
	Pall	047NX50 142NX25	
	Nuclepore	111107 112007	181107 182007
	Millipore	HAWP 047 00 HAWP 142 50	FHLP 047 00 FHLP 142 00
	Selas	83485-02 83486-02	83485-02 83486-02

METHOD 7.4

STRUCTURAL INTEGRITY PROCEDURE

Application

The Structural Integrity Procedure (SIP) is employed to approximate the physical degradation a monolithic waste undergoes in a landfill or when compacted by earthmoving equipment.

Equipment

1. Structural Integrity Tester meeting the specifications detailed in Figure 7.4-1.

2. Sample holders of elastomeric material firm enough to support a cylindrical waste sample 3.3 cm (1.32 in.) in diameter and 7.1 cm (2.84 in.) long.

Procedure

1. Cut a 3.3 cm in diameter by 7.1 cm long cylinder from the waste material. For wastes which have been treated using a fixation process the waste may be cast in the form of a cylinder and allowed to cure for 30 days prior to testing.

2. Place waste into sample holder and assemble the tester. Raise the hammer to its maximum height and drop. Repeat 14 times.

3. Remove solid material from tester and scrap off any particles adhering to sample holder. Weigh the waste to the nearest 0.01 gram and transfer it to the Extractor.

Sub-Section 7.5

EXTRACTORS

Introduction

An acceptable extractor is one which will prevent stratification of a waste sample and extraction fluid and will insure that all sample surfaces continuously contact well-mixed extraction fluid. There are two types of acceptable extractors: 1) stirrers and 2) tumblers. Stirrers consist of a container in which the waste/extraction fluid mixture is agitated by spinning blades. Rotators agitate by turning a sample container end over end through a 360° revolution.

Stirrer

Scope and Application

One such stirrer approved for use in evaluating solid waste is illustrated in Figure 7.5-1. It is a container in which a waste/extraction fluid mixture is agitated by 2 blades spinning at $\geq$ 40 rpm. This extractor can be used with either automatic or manual pH adjustment.

Precautions

1. Large particles ($\geq$ 0.25 in. in diameter) may be ground by the spinning blades or abrade the container. If metal containers are employed this may result in contamination of the EP Extract.

2. Monolithic wastes should not be extracted in the stirrer as they may bend or break the stirring blades.

Summary of Operation

Place waste in extractor, add extraction fluid and stir for the required period of time. Adjust pH while stirrer is in operation by addition of acid through port in cover. pH may be continuously monitored using port in cover designed to accept a pH electrode.

Manufacturers

Extractors of this design may be fabricated by the user or are known to

be available commercially from Associated Design and Manufacturing Co. and Millipore Corporation.

Rotary Extractor

Scope and Application

The rotary extractor consists of a rack or box type device holding a number of plastic or glass bottles which rotate at approximately 29 rpm. Rotary extractors are used with manual pH adjustment.

Precautions

1. Use glass or fluorocarbon bottles for wastes whose EP Extract will be analyzed for organic compounds. For extracts to be analyzed only for metals, polyethylene bottles may be substituted.

2. Be careful not to tighten the screws too far and shatter the bottle when using the design in Figure 7.2-2.

3. Do not use glass bottles for extracting large blocks of waste as these may cause the bottles to shatter.

4. It is recommended that the bottles be alternated in an opposing manner in the apparatus to minimize torque (e.g., when one bottle faces up, the next bottle faces down.) When extracting an odd number of samples, balance the extractor by adding a bottle containing an amount of water approximately equal to the volume in the other bottles.

Equipment

1. Rotary extractors approved for use in evaluating the EP toxicity of solid wastes are illustrated in Figure 7.5-2 and 7.5-3.

2. Plastic or glass bottles sized to fit the particular extractor.

3. The equipment illustrated in Figure 7.5-2 may be fabricated by the user or is available commercially from Associated Design and Manufacturing Co.

4. The equipment illustrated in Figure 7.5-3 is available from the Acurex Corporation.

Summary of Operation

Fill plastic or glass bottles with the solid material. Add distilled deionized water to each bottle and start extractor. Stop extractor after 1 minute and adjust pH. Restart extractor and continue pH adjustment for the first six hours of agitation as described in the "Manual pH Adjustment Procedure" (Section 7.1). After 24 hours of agitation stop extractor, check pH as described and, if within range specified, adjust volume of fluid and remove for liquid/solid separation.

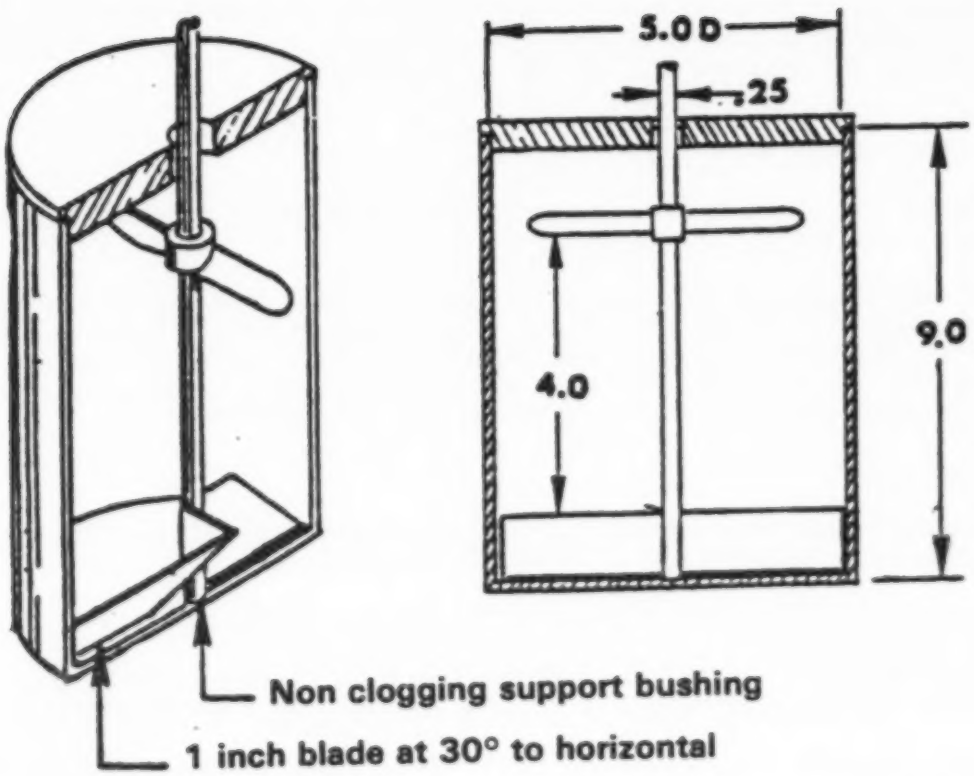


Figure 7.5-1. Extractor

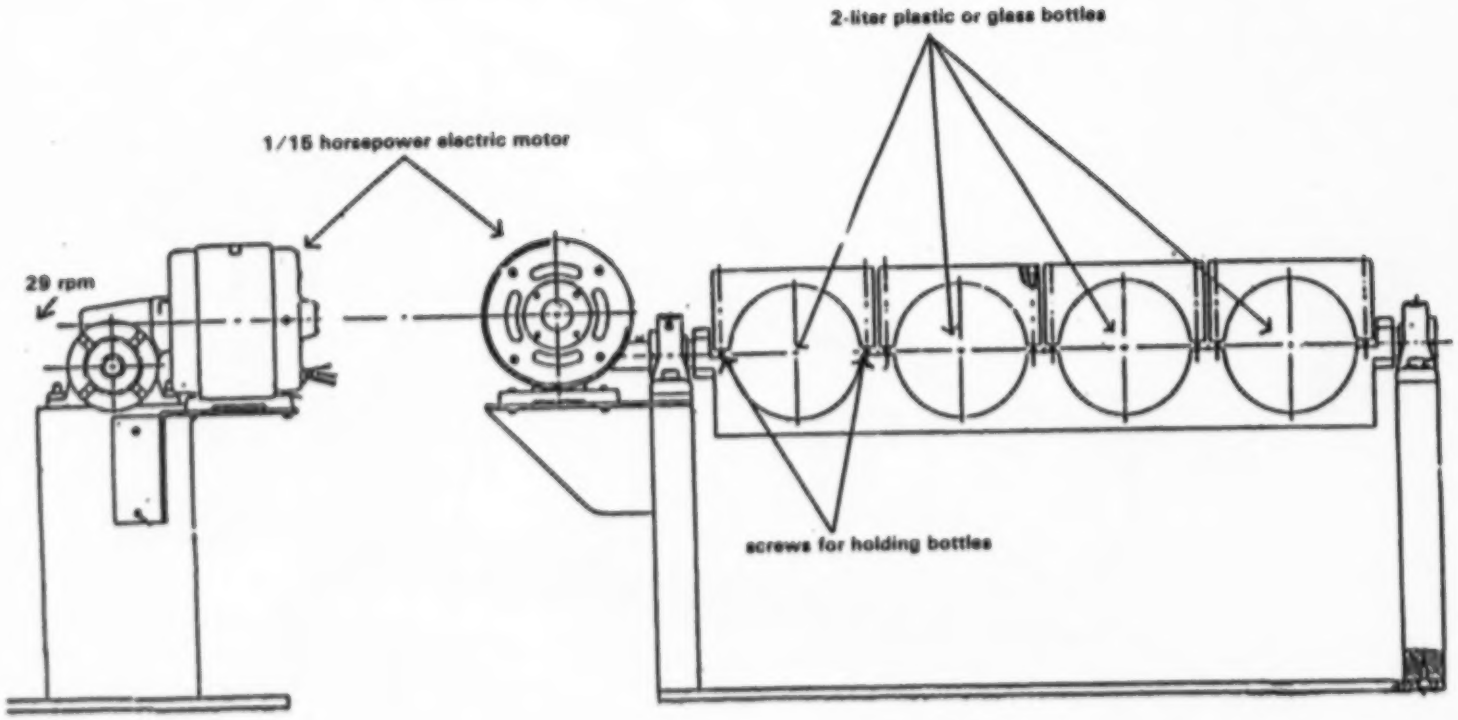


Figure 7.5-2. Rotary Extractor

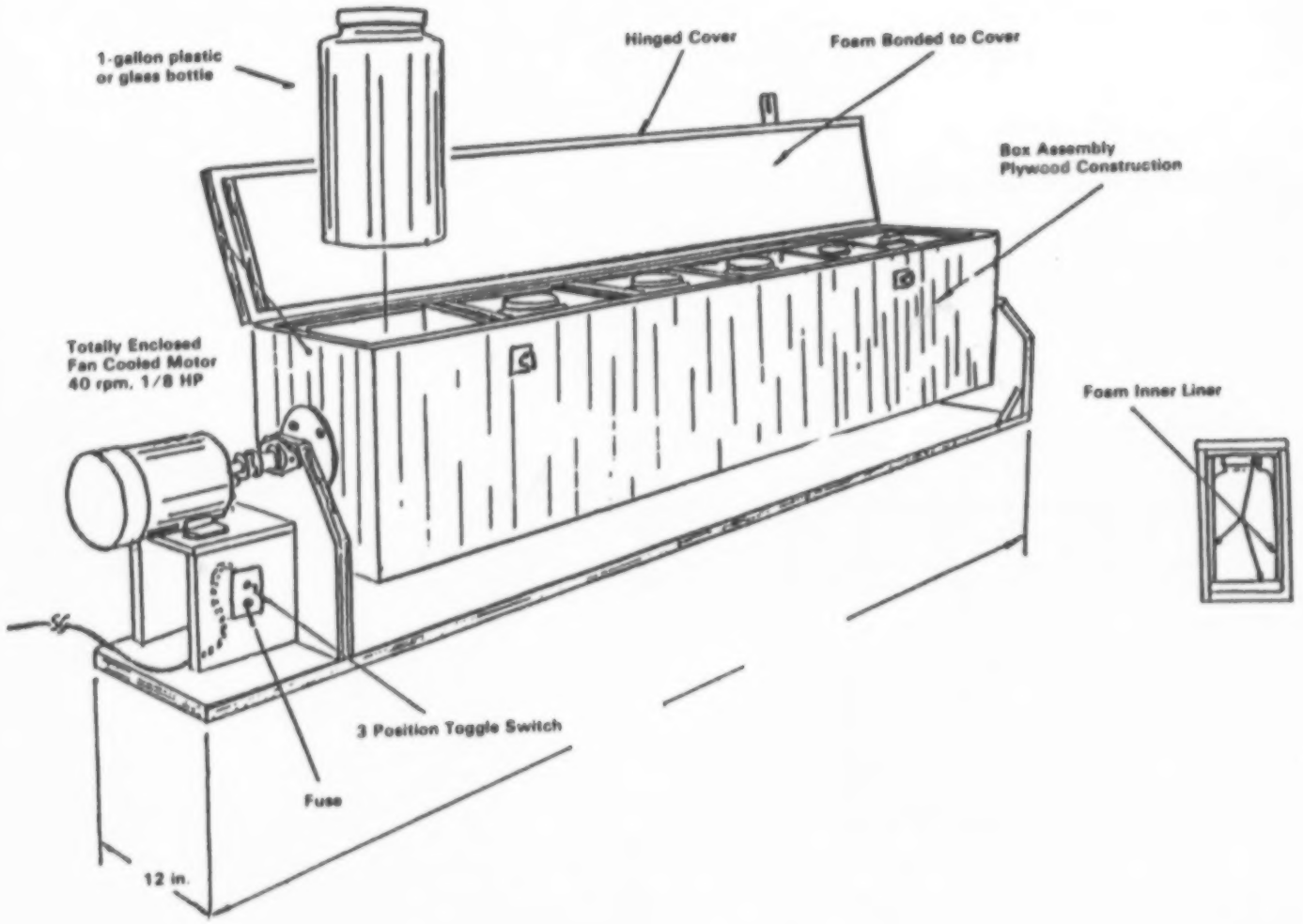


Figure 7.5-3. EPRI/Acurex Extractor

APPENDIX 10

DIGESTION PROCEDURE FOR GRAY IRON FOUNDRY WASTE SAMPLES

1. Acid-clean labware by soaking it at least four hours in 3 percent nitric acid before triple rinsing with deionized water.

2. Transfer enough representative sample materials to a 250-ml beaker to provide at least 30 grams when dry, using a plastic spatula for dry or moist samples and a glass beaker for samples containing a liquid phase. Dry the material at 103 - 105°C to constant weight.

3. Transfer representative 10.00-gram portions of the dry sample to three 250-ml beakers using a plastic spatula.

4. In a hood add 50 ml of nitric acid (1 + 1) to each beaker with sample and to an empty beaker.

5. Cover beakers with watch glasses and evaporate liquids to near dryness on a hotplate making certain that the solutions do not boil. Let digests cool; add 40 ml concentrated nitric acid to each beaker and again evaporate liquids to near drynes without boiling.

6. Let digests cool then add 10 ml nitric acid (1 + 1) to each beaker.

7. Add 30 percent hydrogen peroxide dropwise with caution until 10 ml per beaker have been added.

8. Warm solutions slowly until effervescence subsides.

9. Let digests cool; add 10 ml nitric acid (1 + 1) to each beaker, reflux covered for ten minutes.

10. Let digests cool; filter through Whatman No. 42 filter paper (or equivalent), dilute to 1000 ml with deionized water, and mix.

APPENDIX 11

CHAIN OF CUSTODY RECORD

GRAY IRON FOUNDRY STUDY SAMPLES

Sampling Site Address

Name: _____

Number/Street: _____

City/State: _____ ZIP Code _____

Type of Waste: _____

Waste Process: _____

Other Information: _____

Method of Shipping: _____

Location Sample Sent To: _____

1. Relinquished By: _____ Date __/__/__ Time: _____

   Received By: _____

2. Relinquished By: _____ Date __/__/__ Time: _____

   Received By: _____

3. Relinquished By: _____ Date __/__/__ Time: _____

   Received By: _____

4. Relinquished By: _____ Date __/__/__ Time: _____

   Received By: _____

5. Relinquished By: _____ Date __/__/__ Time: _____

   Received By: _____

APPENDIX 12. ICP DATA FOR EP EXTRACTS (mg/l)

Element		Detection Limit	Field Sample Number 1	2	6	12	12 SPLIT	16	16 SPLIT	19	19 SPLIT	20	22	24	28
Al	AVG	0.16	15.6	10.4	20.4	0.8	BD	38.1	39.8	2.8	2.2	9.2	1.2	6.5	4.9
	STD DEV		0.3	1.5	0.2	0.2	-	4.2	0.4	0.4	0.5	0.9	0.1	0.4	3.7
As	AVG	0.42	BD	1.0	1.3	0.9	1.0	BD	0.8	1.6	1.7	0.9	BD	BD	BD
	STD DEV		-	0.03	0.3	0.2	0.2	-	0.1	0.1	0.1	0.01	-	-	-
B	AVG	0.14	0.3	0.2	3.2	0.2	BD	6.2	5.8	BD	BD	0.5	0.2	0.8	BD
	STD DEV		0.04	0.02	0.2	0.1	-	0.2	0.1	-	-	0.3	0.1	0.05	-
Ba	AVG	0.0084	0.688	0.443	0.053	0.531	0.754	0.388	0.603	0.337	0.366	0.168	0.459	0.140	0.593
	STD DEV		0.032	0.018	0.006	0.012	0.033	0.145	0.013	0.012	0.030	0.027	0.015	0.016	0.509
Be	AVG	0.0065	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
	STD DEV		-	-	-	-	-	-	-	-	-	-	-	-	-
Ca	AVG	0.14	187.4	>300	155.6	>300	>300	193.2	212.0	>300	>300	228.0	213.0	243.4	243.1
	STD DEV		1.4	-	1.1	-	-	25.7	3.2	-	-	4.6	9.8	2.8	201.0
Cd	AVG	0.030	BD	BD	0.93	BD	BD	0.90	0.83	BD	BD	BD	BD	BD	BD
	STD DEV		-	-	0.04	-	-	0.07	0.04	-	-	-	-	-	-
Co	AVG	0.22	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
	STD DEV		-	-	-	-	-	-	-	-	-	-	-	-	-
Cr	AVG	0.019	0.04	0.13	0.68	0.09	BD	0.27	0.28	BD	0.14	0.23	0.09	0.15	0.12
	STD DEV		0.03	0.03	0.04	0.03	-	0.03	0.002	-	0.76	0.12	0.03	0.04	0.07
Cu	AVG	0.025	BD	0.14	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
	STD DEV		-	0.04	-	-	-	-	-	-	-	-	-	-	-
Fe	AVG	0.14	7.3	0.9	5.2	7.4	>30	7.6	8.2	>30	>30	>30	16.0	10.2	>30
	STD DEV		1.4	0.4	2.9	3.6	-	1.6	0.3	-	-	-	4.3	0.7	-
Mg	AVG	0.011	9.56	17.24	>30	12.14	12.20	>30	>30	>30	>30	>30	9.51	19.03	>30
	STD DEV		0.22	0.53	-	0.87	0.16	-	-	-	-	-	0.38	0.20	-
Ni	AVG	0.028	0.31	0.50	0.15	0.19	0.22	0.18	0.22	1.14	0.97	3.41	0.40	0.74	0.16
	STD DEV		0.08	0.01	0.04	0.05	0.02	0.03	0.04	0.34	0.09	0.31	0.04	0.04	0.09
Pb	AVG	0.18	2.9	0.8	19.0	BD	BD	>30	>30	BD	0.7	BD	BD	BD	5.6
	STD DEV		0.6	0.6	0.6	-	-	-	-	-	0.1	-	-	-	4.2
V	AVG	0.020	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
	STD DEV		-	-	-	-	-	-	-	-	-	-	-	-	-
Zn	AVG	0.0068	3.138	0.943	BD	2.021	1.387	>30	>30	3.641	3.243	6.923	0.571	7.838	9.886
	STD DEV		0.146	0.131	-	0.033	0.106	-	-	0.405	0.093	0.736	0.089	0.516	8.126

BD indicates value below Detection limit (3 sigma) shown in first column.
Sample 8 extract was not analyzed by ICP.

(continued)

APPENDIX 12 (Continued). ICP DATA FOR EP EXTRACTS (mg/l)

Element		Detection Limit	Field Sample Number 34	36	40	42	44	46	46 SPLIT	50	51	52	54	54 SPLIT	56
Al	AVG	0.16	20.1	6.3	7.6	0.4	22.6	0.5	1.6	BD	BD	38.7	8.8	7.3	4.7
	STD DEV		0.8	0.2	0.3	0.02	8.1	0.04	0.1	-	-	0.8	1.4	0.1	0.1
As	AVG	0.42	BD	0.9	1.6	0.3	2.0	0.4	0.3	BD	BD	3.0	0.7	0.7	0.6
	STD DEV		-	0.3	0.01	0.03	0.6	0.1	0.1	-	-	0.03	0.1	0.01	0.02
B	AVG	0.14	0.8	0.4	BD	0.4	4.3	BD	BD	0.2	0.1	10.1	2.1	2.4	0.2
	STD DEV		0.1	0.1	-	0.01	0.7	-	-	-	-	0.2	0.3	0.1	0.04
Ba	AVG	0.0084	0.190	0.441	0.868	0.555	0.687	0.393	0.506	0.092	0.072	1.760	1.692	1.986	0.700
	STD DEV		0.028	0.024	0.050	0.022	0.060	0.010	0.041	-	-	0.084	0.300	0.050	0.008
Be	AVG	0.0065	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD	BD
	STD DEV		-	-	-	-	-	-	-	-	-	-	-	-	-
Ca	AVG	0.14	107.4	>300	BD	122.0	146.3	41.8	48.6	88.6	85.9	230.2	>300	>300	>300
	STD DEV		6.0	-	-	0.5	15.1	1.9	1.7	-	-	13.4	-	-	-
Cd	AVG	0.030	1.51	BD	0.07	0.52	1.24	BD	BD	0.19	BD	1.80	0.25	0.20	BD
	STD DEV		0.02	-	0.003	0.01	0.14	-	-	-	-	0.24	0.04	0.01	-
Co	AVG	0.22	BD	BD	0.2	BD	0.4	BD	BD	BD	BD	0.6	BD	BD	BD
	STD DEV		-	-	0.02	-	0.1	-	-	-	-	0.01	-	-	-
Cr	AVG	0.019	0.19	0.25	BD	0.15	1.60	BD	BD	0.02	0.20	2.23	0.13	0.15	0.14
	STD DEV		0.01	0.03	-	0.003	0.26	-	-	-	-	0.02	0.01	0.01	0.01
Cu	AVG	0.025	5.11	BD	0.09	BD	BD	BD	BD	BD	BD	BD	0.56	BD	0.10
	STD DEV		0.47	-	0.002	-	-	-	-	-	-	-	0.14	-	0.01
Fe	AVG	0.14	0.9	2.7	>30	4.0	>30	>30	>30	BD	BD	>30	6.4	17.0	>30
	STD DEV		0.2	0.1	-	1.1	-	-	-	-	-	-	1.0	2.3	-
Mg	AVG	0.011	>30	>30	>30	13.58	13.28	2.57	3.06	24.23	23.64	>30	8.53	9.23	12.62
	STD DEV		-	-	-	0.03	0.74	0.06	0.23	-	-	-	1.41	0.14	0.10
Ni	AVG	0.028	4.28	0.70	0.68	0.24	0.72	0.50	0.46	BD	BD	0.57	0.21	0.28	0.26
	STD DEV		0.07	0.08	0.04	0.004	0.15	0.01	0.03	-	-	0.02	0.04	0.05	0.02
Pb	AVG	0.18	8.9	0.8	0.9	0.7	1.7	0.1	0.2	0.2	0.3	21.6	17.2	8.0	0.5
	STD DEV		1.3	0.2	0.1	0.04	0.5	0.02	0.02	-	-	5.0	2.6	0.4	0.02
V	AVG	0.020	BD	BD	BD	BD	0.55	BD	BD	BD	BD	0.99	BD	BD	BD
	STD DEV		-	-	-	-	0.30	-	-	-	-	0.01	-	-	-
Zn	AVG	0.0068	>30	5.194	15.530	>30	12.147	3.546	16.114	6.410	0.690	BD	>30	>30	8.088
	STD DEV		-	0.051	0.780	-	1.486	4.034	0.806	-	-	-	-	-	0.118

(continued)

BD indicates value Below Detection limit (3 sigma) shown in first column.

APPENDIX 12 (Continued). ICP DATA FOR EP EXTRACTS (mg/l)

Element		Detection Limit	Field Sample Number										
			56 SPLIT	58-2-S	60	64	66	66 SPLIT	68	68 SPLIT	70	74	78
Al	AVG	0.16	12.1	2.7	5.8	13.0	30.8	30.5	10.9	11.9	19.4	5.9	3.6
	STD DEV		11.4	0.4	0.7	0.5	0.4	1.1	0.1	1.0	0.2	0.1	0.8
As	AVG	0.42	1.4	0.9	1.1	BD	1.6	0.5	BD	0.3	1.1	0.7	BD
	STD DEV		1.2	0.04	0.02	-	0.05	0.05	-	0.1	0.02	0.01	-
B	AVG	0.14	1.1	0.2	BD	0.7	2.2	2.4	1.0	1.1	BD	BD	0.2
	STD DEV		2.3	0.04	-	0.04	0.4	0.3	0.01	0.2	-	-	0.2
Ba	AVG	0.0084	0.645	0.535	0.826	0.116	BD	0.158	0.243	0.374	0.729	0.723	0.329
	STD DEV		0.198	0.615	0.007	0.005	-	0.005	0.003	0.167	0.013	0.012	0.166
Be	AVG	0.0065	BD	BD	BD	BD	24.276	BD	BD	BD	BD	BD	BD
	STD DEV		-	-	-	-	0.624	-	-	-	-	-	-
Ca	AVG	0.14	>300	>300	>300	9.1	2.0	24.5	15.7	37.7	>300	>300	138.7
	STD DEV		-	-	-	0.2	0.1	0.8	0.1	37.5	-	-	34.5
Cd	AVG	0.030	BD	BD	0.08	BD	0.22	1.91	0.07	0.07	0.54	BD	BD
	STD DEV		-	-	0.01	-	0.03	0.07	0.004	0.01	0.04	-	-
Co	AVG	0.22	BD	BD	BD	BD	0.8	0.3	BD	BD	0.2	BD	BD
	STD DEV		-	-	-	-	0.04	0.01	-	-	0.01	-	-
Cr	AVG	0.019	0.66	0.34	BD	0.12	0.38	0.80	0.29	0.33	BD	BD	0.12
	STD DEV		1.06	0.02	-	0.005	0.001	0.01	0.01	0.01	-	-	(0.002)
Cu	AVG	0.025	0.06	0.06	0.07	0.08	14.5	0.38	0.43	0.47	BD	BD	0.12
	STD DEV		0.02	0.04	0.01	0.10	0.3	0.02	0.01	0.05	-	-	0.09
Fe	AVG	0.14	>30	10.9	>30	4.5	5.0	14.0	2.7	3.4	>30	>30	0.9
	STD DEV		-	8.0	-	0.3	0.1	0.6	0.04	0.6	-	-	0.6
Mg	AVG	0.011	16.61	>30	28.27	9.50	BD	5.15	2.72	3.26	>30	13.84	9.05
	STD DEV		5.24	-	0.48	0.23	-	0.16	0.04	0.87	-	0.42	0.72
Ni	AVG	0.028	0.23	0.16	0.40	0.12	0.18	2.67	1.50	1.57	0.74	0.29	0.78
	STD DEV		0.05	0.01	0.05	0.004	0.01	0.08	0.02	0.04	0.07	0.03	0.04
Pb	AVG	0.18	0.6	0.3	2.0	BD	12.4	0.2	0.2	1.2	10.3	0.4	1.1
	STD DEV		0.1	0.03	0.2	-	0.3	0.02	0.02	1.8	0.9	0.01	1.7
V	AVG	0.020	0.27	BD	BD	BD	0.75	0.75	0.11	0.12	BD	BD	BD
	STD DEV		0.46	-	-	-	0.02	0.03	0.002	0.02	-	-	-
Zn	AVG	0.0068	10.401	5.835	11.155	1.232	1.727	1.778	1.102	4.564	BD	8.580	4.622
	STD DEV		2.841	0.423	0.262	0.659	0.078	0.071	0.016	5.650	-	0.195	4.794

BD indicates value Below Detection limit (3 sigma) shown in first column.

APPENDIX 13. ICP DATA FOR WASTE DIGESTS (mg/kg)

Element		Detection Limit	Field Sample Number										
			1	2	6	8	12	12 SPLIT	16	16 SPLIT	19	19 SPLIT	20
Al	AVG	16	3800	2910	15400	40	300	750	13200	>6000	2390	2800	4000
	STD DEV		150	150	300	10	20	100	90	-	420	470	380
As	AVG	42	90	80	120	BD	BD	BD	BD	BD	90	80	BD
	STD DEV		2	10	7	-	-	-	-	-	30	10	-
B	AVG	14	30	60	560	BD	480	420	510	170	340	370	270
	STD DEV		2	10	10	-	40	30	20	3	40	10	110
Ba	AVG	0.84	219.9	95.5	177	BD	131.9	145.8	248	325.7	157.6	155.0	135.7
	STD DEV		3.9	6.2	4	-	9.8	25.3	81	9.3	58.7	50.0	3.5
Be	AVG	0.65	BD	BD	2.5	BD	BD	BD	BD	BD	BD	BD	BD
	STD DEV		-	-	0.4	-	-	-	-	-	-	-	-
Ca	AVG	14	8820	16630	11620	BD	14840	14170	16140	17310	>30000	>30000	7840
	STD DEV		170	1380	160	10	1500	1490	230	390	-	-	240
Cd	AVG	3.0	9	BD	84	BD	14	12	40	37	12	13	10
	STD DEV		1	-	2	-	1	1	2	12	4	4	2
Co	AVG	22	40	40	40	BD	40	BD	BD	BD	40	40	BD
	STD DEV		2	4	10	-	3	-	-	-	3	2	-
Cr	AVG	1.9	299	183	279	BD	773	617	210	157	241	262	185
	STD DEV		60	2	4	-	97	32	2	7	13	2	38
Cu	AVG	2.5	193	72	1425	BD	334	338	335	296	389	353	225
	STD DEV		28	5	25	-	52	72	5	10	209	90	60
Fe	AVG	14	>3000	>3000	>30000	BD	>3000	>3000	>30000	>3000	>3000	>3000	>3000
	STD DEV		-	-	-	-	-	-		-	-	-	-
Mg	AVG	1.1	>3000	>3000	23140	38	1138	1000	5071	>3000	>3000	>3000	>3000
	STD DEV		-	-	170	4	180	81	42	-	-	-	-
Ni	AVG	2.8	385	243	51	BD	81	69	46	124	247	317	185
	STD DEV		26	34	4	-	6	6	2	7	26	16	11
Pb	AVG	18	2010	210	20500	BD	360	330	18780	>3000	800	790	930
	STD DEV		40	(0.8)	200	-	60	80	1830	-	220	380	30
V	AVG	2.0	48	78	BD	BD	BD	-	BD	30	BD	BD	BD
	STD DEV		1	8	-	-	-	-	-	9	-	-	-
Zn	AVG	0.68	694.0	189.4	>30000	26.0	355.4	354.4	12720	>3000	436.0	407.7	1003.0
	STD DEV		11.6	9.7		0.6	54.8	19.1	250	-	135.5	57.6	15.5

(continued)

APPENDIX 13 (Continued). ICP DATA FOR WASTE DIGESTS (mg/kg)

Element		Field Sample Number												
		22	24	28	34	36	40	42	44	46	46 SPLIT	52	54	54 SPLIT
Al	AVG	2310	1540	>6000	>6000	>6000	5780	>6000	4620	>6000	>6000	>6000	4060	3740
	STD DEV	140	230	-	-	-	700	-	80	-	-	-	50	60
As	AVG	BD	BD	60	230	BD	320	70	300	520	460	380	100	100
	STD DEV	-	-	10	3	-	30	10	3	80	100	360	2	2
B	AVG	40	480	500	800	400	370	BD	1320	BD	BD	870	BD	BD
	STD DEV	4	20	10	4	20	40	-	20	-	-	20	-	-
Ba	AVG	96.3	123.8	198.5	148.9	151.6	146.3	75.9	96.4	962.9	921.5	807.8	306.1	281.4
	STD DEV	7.1	1.5	10.3	1.0	6.4	6.0	1.0	2.2	81.2	76.9	46.5	24.3	224.2
Be	AVG	BD	-	2.0	BD	BD	BD	1.3	BD	5.6	5.7	BD	BD	BD
	STD DEV	-	-	0.1	-	-	-	0.5	-	1.5	0.4	-	-	-
Ca	AVG	7330	8030	>30000	19000	17120	>30000	7290	1210	BD	BD	13830	13530	12020
	STD DEV	160	80	-	140	650	-	80	190	-	-	200	260	310
Cd	AVG	7	16	28	90	12	11	40	145	8	8	901	18	16
	STD DEV	1	3	3	1	1	5	2	3	3	1	4	0.4	1
Co	AVG	BD	40	30	60	30	60	BD	110	40	40	90	BD	BD
	STD DEV	-	4	1	4	5	3	-	10	2	3	3	-	-
Cr	AVG	BD	299	328	2014	404	316	BD	1865	302	279	406	BD	BD
	STD DEV	7	8	4	16	16	26	-	26	94	42	14	-	-
Cu	AVG	50	362	455	1985	369	200	265	>3000	138	214	>3000	388	359
	STD DEV	1	3	54	12	4	27	3	-	89	42	-	9	4
Fe	AVG	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000
	STD DEV	-	-	-	-	-	-	-	-	-	-	-	-	-
Mg	AVG	613	1698	>3000	1952	>3000	>3000	2225	2452	>3000	>3000	>3000	1223	1133
	STD DEV	38	27	-	7	-	-	56	27	-	-	-	18	27
Ni	AVG	52	101	76	1361	183	134	33	367	36	37	186	44	45
	STD DEV	5	2	3	7	3	13	1	4	13	10	15	1	2
Pb	AVG	40	300	>3000	>3000	870	600	2130	>3000	150	160	>3000	2340	2080
	STD DEV	4	10	-	-	50	20	40	-	20	10	-	20	30
V	AVG	5	BD	BD	47	BD	107	7	32	7	14	216	33	32
	STD DEV	0.3	-	-	1	-	38	2	5	8	2	196	1	1
Zn	AVG	131.1	1013.7	>3000	>3000	691.3	1605.1	>3000	>3000	555.5	675.2	BD	>3000	>3000
	STD DEV	15.0	47.3	-	-	11.8	30.2	-	-	209.6	85.9	-	-	-

(continued)

APPENDIX 13 (Continued). ICP DATA FOR WASTE DIGESTS (mg/kg)

Element		Field Sample Number										
		56	56 SPLIT	58	60	64	66	66 SPLIT	68	70	74	78
Al	AVG	4030	3080	5310	5650	>6000	3130	3020	1940	>6000	5900	4080
	STD DEV	210	180	40	520	-	110	100	60	-	40	110
As	AVG	110	170	90	220	90	220	210	200	160	200	100
	STD DEV	10	10	10	10	1	10	10	10	10	10	20
B	AVG	230	1010	80	300	80	820	790	800	280	300	240
	STD DEV	10	20	-	10	-	60	20	60	2	4	2
Ba	AVG	105.1	53.6	50.4	143.4	72.8	116.1	113.3	136.9	123.0	299.8	105.8
	STD DEV	10.2	5.3	2.9	12.0	4.6	5.4	1.3	0.5	1.9	18.2	2.0
Be	AVG	80	80	80	80	80	80	80	80	1.2	80	80
	STD DEV	-	-	-	-	-	-	-	-	0.8	-	-
Ca	AVG	12850	4090	14220	27040	19360	2290	2260	1170	10740	18260	13780
	STD DEV	510	140	470	930	430	80	60	4	110	140	620
Cd	AVG	5	32	6	13	80	163	158	21	104	13	10
	STD DEV	0.1	1	1	0.2	-	7	8	6	3	4	0.1
Co	AVG	80	70	80	60	80	70	60	70	30	30	80
	STD DEV	-	1	-	3	-	4	1	3	1	10	-
Cr	AVG	199	714	80	389	78	2562	2367	2151	22	252	198
	STD DEV	7	9	-	28	3	210	63	265	3	6	92
Cu	AVG	193	467	174	362	191	556	528	629	662	661	218
	STD DEV	8	5	23	23	6	19	15	28	21	14	49
Fe	AVG	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000	>3000
	STD DEV	-	-	-	-	-	-	-	-	-	-	-
Hg	AVG	1212	791	1741	2234	8564	1004	981	513	2937	1653	1215
	STD DEV	17	23	24	80	110	34	32	16	96	37	40
Mi	AVG	56	190	36	121	77	1036	937	711	66	124	52
	STD DEV	4	3	3	6	1	44	20	52	5	12	2
Pb	AVG	340	720	230	1670	90	380	360	400	2910	1540	320
	STD DEV	10	10	10	60	1	5	10	10	170	5	10
V	AVG	41	24	24	129	20	58	55	107	44	66	39
	STD DEV	4	1	2	10	0.3	3	2	11	4	5	3
Zn	AVG	774.1	857.8	546.9	1015.6	103.2	588.8	547.5	544.8	>3000	1423.2	819.8
	STD DEV	27.4	12.8	29.9	56.5	0.8	8.3	12.7	21.5	-	46.5	19.2